NOTICE

AVIS

UNIVERSITY OF ALBERTA

ORTHODONTIC ELASTOMERIC CHAIN

- Effect of Sterilization on Force Decay
- Effect of Pre-soaking on Force decay
- Force / Extension Characteristics

BY

BRIEN WHITFIELD STACKHOUSE ©

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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RELEASE FORM

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Master of Science in Clinical Sciences

(Orthodontics)

1991

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Date: 25 April 1991

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled:

"ORTHODONTIC ELASTOMERIC CHAIN

- Effect of Sterilization on Force Decay
- Effect of Pre-soaking on Force Decay
- Force / Extension Characteristics"

submitted by Brien Whitfield Stackhouse in partial fulfilment of the requirements for the degree of Master of Science in Clinical Sciences (Orthodontics).

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Date: March 26/91

DEDICATION

This work is dedicated to my wife Susan and to my children Jessica and Matthew. Their support, encouragement and willingness to sacrifice has allowed me to pursue my interest in orthodontics and is responsible for any success that I may enjoy.

ABSTRACT

The purposes of this study were to investigate the effect of sterilization (by ethylene oxide gas and by chemical vapor autoclave) and of presoaking in water on the force decay properties of one brand of orthodontic elastomeric chain. As well, the force/extension characteristics of the material over distances simulating cuspid retraction were determined.

During force decay testing chains were stored in water at 37°C between tests. Tooth movement was simulated at 0.25mm per week. Force produced was measured at initial placement and after 1 hour, 1 day, 1 week, 2 weeks, 3 weeks, and 4 weeks.

Ethylene Oxide gas sterilization produced no undesirable effects on force decay. Chemical vapor autoclave resulted in shrinkage of chains and less consistent force delivery. Presoaking chains in water resulted in a decreased force initially, with force levels from 1 week to 4 weeks not different from the control. Ethylene Oxide gas sterilization was felt to be a suitable means of sterilizating these materials. Chemical vapor autoclave was not recommended.

Force/Extension characteristics were determined for a three loop length of chain stretched to simulate placement on the first molar, the second bicuspid and the cuspid.

Both three and four loop lengths of chain were tested. At the distances used, the relationship between distance stretched and force produced was linear. Recognition of this linear relationship will allow the clinician to better control the forces produced when using chains at these distances. The relationship between force and distance stretched at distances greater than those studied needs further investigation.

ACKNOWLEDGEMENTS

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INTRODUCTION:

Elastomeric chain materials have been used in orthodontics for several years to supply forces necessary for tooth movement. They are referred to as alastiks, plastic modules, plastic alastiks, elastomerics, synthetic elastomers, synthetic elastics and polyurethane chain elastics. The chains are manufactured in various forms usually differing in the number of loops per unit length (so called "open space" or "closed space" chain). Elastomeric materials are made up of amorphous polymers of polyurethanes. When this material is stretched the polymer chains can uncoil and stretch or slip past one another by breaking the weak cross links that are present.The materials elastic properties are the result of uncoiling and stretching while slippage of the polymer chains leads to plastic deformation. It is this plastic deformation that results in force decay of the orthodontic elastomeric chain.[1]

These materials are marketed under various brand names. The manufacturers claim that these materials are "highly resistant to breakage, loss of elastic force and deterioration in the oral environment"[2].They also claim that the product "remains active over a long period of time and has good elastic memory"[3]. While the materials do have elastic properties it is well recognized that the forces that they generate undergo decay over a period of time[1,4-19].

This material is commercially available in spools of several feet in length which necessitates repeated handling in the orthodontic office and could warrant its sterilization or disinfection. The clinician must be aware of any effect that sterilization could have on its properties and especially its ability to produce and sustain forces needed for orthodontic tooth movement. If, for example, sterilization alters the material such that the force decay is greatly increased, more frequent appointments may be needed to place new chains. Conversely, if the force decay is reduced, smaller initial forces could be applied with the assurance that sufficient force for tooth movement would remain at the end of the between appointment period. If the material is found to be adversely affected by sterilization, it would be necessary to review the manner in which these materials are handled in the orthodontic office, or the manner in which they are packaged by the manufacturer. No references in the literature to investigations of the effect of sterilization on these materials could be found.

The force/extension characteristics of these materials have not been well documented in the literature. This information would be of great use to the clinician especially with regard to optimizing tooth movement and minimizing patient discomfort. A better understanding of these characteristics would aid the clinician when faced with the decision of how to utilize the chain. For example, the configuration often employed when using elastomeric chain for cuspid retraction is to engage the molar, the second bicuspid, and then the cuspid. Initially a four loop length of chain is used, with a three loop length being placed at some time subsequent to this, as the space is closed. The decision to change from the four loop to the three loop chain is often made on a subjective basis. Understanding the force/extension characteristics of the material would allow the clinician to make this decision with confidence as to the amount of force being generated, thus avoiding the use of either excessive or inadequate force. Excessive force could increase patient discomfort or result in tooth movement via indirect resorption whereas inadequate force could result in less efficient tooth movement, or no movement at all, thereby increasing treatment time.

Force decay of these materials has been characterized as a rapid initial decay, especially in the first 24 hours, followed by a more gradual decay over the next three to four weeks. In order to ensure that an adequate force level will exist over the time period between appointments the clinician may have to place higher forces initially to account for the subsequent decay. By reducing or eliminating the early rapid decay, the application of more consistent force levels for tooth movement would be possible. This would allow the use of smaller initial forces and still ensure that sufficient force would exist for tooth movement over the next few weeks. Patient discomfort may also be lessened.

When an elastomeric chain is placed in the mouth it warms to near body temperature and becomes soaked in saliva. If the rapid initial decay is related to the warming and soaking, it may be possible to reduce the initial force generated by pre-warming and pre-soaking the chain prior to its placement in the mouth.

a. PURPOSE of the STUDY

The purposes of this in vitro study are :

- to determine the effect of two methods of sterilization on the force decay properties of one brand of orthodontic elastomeric chain.

- to determine if pre-soaking the material in room temperature water for 1 hour prior to testing will reduce the high initial force and still produce force levels sufficient for tooth movement over four weeks.

- to determine if pre-soaking the material in water at 40^{o}C for 1 hour prior to testing will reduce the high initial force and still produce force levels sufficient for tooth movement over four weeks.

- to determine the effect of a 4 month shelf life on the force decay properties of one brand of orthodontic elastomeric chain

- to determine the force/extension characteristics of one brand of orthodontic elastomeric chain over distances appropriate to a simulation of cuspid retraction.

b. RESEARCH QUESTIONS

i) What is the effect of sterilization by ethylene oxide gas on the force decay properties of one brand of orthodontic elastomeric chain?

ii) What is the effect of sterilization by chemical vapor autoclave on the force decay properties of one brand of orthodontic elastomeric chain?

iii) Will pre-soaking one brand of orthodontic elastomeric chain in water result in a decreased initial force level and still maintain force levels sufficient for tooth movement over a four week period?

iv) Will pre-soaking and pre-warming one brand of orthodontic elastomeric chain result in a decreased initial force level and still maintain force levels sufficient for tooth movement over a four week period?

v) What is the effect of a four month shelf life on the force decay properties of one brand of orthodontic elastomeric chain?

vi) What are the force/extension characteristics of one brand of orthodontic elastomeric chain at distances used in cuspid retraction?

c. HYPOTHESES

H_1: A single sterilization by ethylene oxide gas:

H_O: Will not significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_A: Will significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_2: Four separate sterilizations by ethylene oxide gas:

H_O: Will not significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_A: Will significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_3: A single sterilization by chemical vapor autoclave:

H_O: Will not significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_A: Will significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_4: Four separate sterilizations by chemical vapor autoclave:

H_O: Will not significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_A: Will significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_5: Pre-soaking one brand of orthodontic elastomeric chain in room temperature water for 1 hour:

H_O: Will not result in a significantly reduced initial force level.

H_A: Will result in a significantly reduced initial force level.

H_5: Pre-soaking one brand of orthodontic elastomeric material in room temperature water for 1 hour:

H_O: Will not result in force levels sufficient to maintain tooth movement over a four week period.

H_A: Will result in force levels sufficient to maintain tooth movement over a four week period.

H_7: Pre-soaking one brand of orthodontic elastomeric chain in water at 40^{o}C for 1 hour:

H_O: Will not result in a significantly reduced initial force level.

H_A: Will result in a significantly reduced initial force level.

H_8: Pre-soaking one brand of orthodontic elastomeric chain in water at 40^{o}C for 1 hour:

H_O: Will not result in force levels sufficient to maintain tooth movement over a four week period.

H_A: Will result in force levels sufficient to maintain tooth movement over a four week period.

H_9: A 4 month shelf life:

H_0: Will not significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

H_A: Will significantly affect the force decay properties of one brand of orthodontic elastomeric chain.

II. REVIEW of the LITERATURE:

a. FORCE DECAY

Andreasen and Bishara (1970)[4] compared force decay of elastomeric chains and latex elastics at molar to molar distances. They found that the elastomers were permanently deformed over the test period and that force decay occurred most rapidly in the first 24 hours after stretching. The authors noted a high degree of variability in the forces generated. Bishara and Andreasen (1970)[5] presented a further comparison of elastomeric chains and latex elastics as used in inter-arch mechanics (Class II and Class III elastics). They found a rapid initial decay rate with the elastomeric chains, especially in the first 24 hrs., and a large variability in the force generated. The large amount of variability may have been due to the nature of the material, or it may have been related to the stretching and restretching that the chains were subject to in this study. Ware (1970)[6] demonstrated considerable force decay in the first ten minutes after stretching. Hershey & Reynolds (1975)[7] found that the rate of force decay was greater when tooth movement was simulated and claimed that the rate of decay was not related to the magnitude of the initial force. Kovatch et.al. (1976)[8] showed that the rate of stretch affected the rate of decay. They also claimed that the initial force did influence the decay rate, with higher initial forces producing more rapid decay.

Force decay in vivo was investigated by Ash & Nikolai (1978)[9] and was found to occur more quickly and to a greater extent after one week in the mouth than with in vitro conditions. The effect of tooth movement was negated by the use of intra-oral jigs to hold the material at a constant stretch. Young & Sandrik (1979)[10] showed that prestretching resulted in a statistically significant reduction in force decay in one of two types of chain tested. The magnitude of the reduction was small (approximately 7 to 10 grams). A test of elastomeric threads by Howard & Nikolai (1979)[11] indicated that in vivo force decay was greater than in vitro decay. They too, used intra-oral jigs to prevent tooth movement. Brantley et.al. (1979)[12] showed that pre-stretching in water at 37°C resulted in a reduced force decay. Three weeks of prestretching was more effective than 24 hrs. Because the material demonstrated an ability to recover from prestretching, the greatest reduction in force decay was seen when testing took place immediately after removal from the prestretching apparatus. DeGenova et.al. (1985)[13] found that when chains were thermally cycled, the force decay was reduced. The authors felt that thermal cycling would better represent temperature variations that normally occur in the oral environment. Small differences, in the range of 5% and less were noted. An intra-oral test by Kuster et.al. (1986)[14] showed that force decay occurred more rapidly and to a greater extent when compared to in vitro tests. Chung et.al. (1989)[15] investigated initial force levels produced by different clinicians in using chains for cuspid retraction. They found considerable variation amongst both operators and materials. Huget et.al. (1990)[16] presented evidence to suggest that exposure of elastomeric chains to water resulted in an increase of force decay because of formation of hydrogen bonds between water molecules and the polymer macromolecules. These acted as plasticizers, allowing chain slippage to occur more easily. They further suggested that degradation of these materials (addition of water resulting in cleavage of ester linkages) is catalyzed by acid. However a study by Ferriter et.al. (1990)[17] on the effect of pH on these materials does not support this. Using pH values within the range found intra-orally, they discovered that force decay is greater in a basic environment for all but one brand of chain.

No references were found that examined the effect of sterilization on these materials.

b. FORCE/EXTENSION

Bishara & Andreasen (1970)[5] refer to the load extension relation of elastomeric chains as being "not linearly proportionate". They did not provide a further description of the relationship. Ware (1971)[6] found that elastomeric chain had a load/extension ratio of approximately 48 gms per mm stretch. This stiffness was reduced when chains were pre-soaked in water at 37°C for 24 hrs. prior to testing. The load/extension curve was non-linear. The sample and methodology are incompletely described and the data were not subjected to statistical analysis. Kovatch et.al. (1976)[8] demonstrated that the rate of stretch affected the load/extension behaviour. At all rates of stretch the load/extension curve was non-linear. No statistical analysis of the data was reported. In a comprehensive study Rock et.al. (1985)[18] determined the force/extension characteristics of several brands of chain material. All shared a common pattern described as an initial linear relation followed by a non-linear "transition period" and then another linear relation. The force level at the transition region differed amongst brands but was generally in the range of 200 to 300 gms. An in vivo investigation was attempted by Rock et.al. (1986)[19]. Their results showed that values for elastomeric chain stiffness decreased from 37% to 67% after one month in the mouth. Unfortunately the study was not well controlled.

c. FORCE REQUIRED to MOVE a CUSPID

The magnitude of force needed to move tooth is dependant on many factors[20] including;

- type of tooth movement; a tipping movement requires less force than bodily movement of the same tooth.
- type of force; e.g. continuous or intermittent. A continuous force may also be interrupted.
- size and number of roots; A multi-rooted tooth will require more force applied because of the larger root surface area. Similarly, a tooth with a large root will require more force for movement than a smaller rooted tooth.
- histologic factors; These include differences in the cellularity of the PDL due to normal individual variation or age.
- appliance factors; Friction inherent in the appliance and forc ecay of the appliance, elastic etc. must be accoun

Sev uthors have investigated the force required to retract a cuspid[20-26]. Results of these studies are summarized in TABLE 1.

Some of these studies moved teeth primarily by tipping while others attempted pure bodily movement. Variability due to age of the patients and the patients individual physiologic response is also present, as are measurement errors resulting from difficulty in finding a stable reference point. In addition, deformation of bone, especially at the alveolar crest, can cause an over estimation of actual tooth movement. These problems notwithstanding, the range of force for optimum tooth movement indicated by these studies is approximately 100 - 300 gms.

TABLE 1. Summary of studies on force required to move a cuspid.

Author	Threshold	Optimum	Excessive
Smith & Storey	60-100 gms	150-200 gms	400-600 gms
Reitan	-	150-250 gms (maxillary) 100-200 gms (mandibular)	-
Hixon et.al.	-	movement increased as force increased up to 300 gms	none up to 1000 gms
Boester & Johnston	55 gms (moved tooth more slowly)	140-310 gms	-
Nikolai (theoretical)	-	210 gms	-
Quinn & Yoshikawa	4 gms	100-200 gms	above 200 gms tooth will move but rate does not increase

d. SUMMARY

Previous investigations have shown that elastomreic chain materials undergo a rapid initial decay. In the first day 50% - 70% of the initial force was lost. A more gradual loss of force occurs thereafter. Force decay occured more rapidly and to a greater extent intra-orally than in vitro. Force decay was affected by simulated tooth movement, rate of stretch, distance stretched and by exposure to water prior to testing.

The force/extension characteristics have been described as non-linear. Pre-soaking in water, rate of stretch and the oral environment all affected these characteristics.

The force needed to accomplish movement of a cuspid is in the 100 - 300 gm. range.

III. MATERIALS and METHODS:

a. SAMPLE

Ormco Generation II open space grey Power Chain* was used in all tests. This relatively new product from a major manufacturer, is widely used in orthodontic practice and has not been previously studied. Material from the same manufacturer's lot number was used to eliminate any variation that may have been caused by age and previous handling or storage of the material.

Chains were cut into four loop lengths and randomly assigned to the experimental groups. When a three loop length of chain was required, a single loop was later removed from the chain. Chains were then placed in self sealing sterilization bags (30 chains per bag) which were opened when testing commenced.

Sample size: - all force decay groups consisted of 30 chains per experimental group.

- all force/extension groups contained 10 chains per experimental group.

---

* # 639-0011, Ormco Corporation 1332 South Lone Hill Ave. Glendora, California 91740

b. INSTRUMENTATION

i. Measuring Apparatus

All force measurements were done using the force/moment measuring apparatus at the University of Alberta , Dept. of Mechanical Engineering (FIG. 1). This apparatus has been described previously[18]. Using pairs of binocular beams and strain gauge load cells the apparatus measures forces and moments created by such things as T-loops and retraction loops. Output from the load cells are transmitted to a Vishay / Ellis 20 Indicator Scanner and then to an IBM PC via a multiplexer. Using pre-determined calibration constants, a computer program then calculates the forces and moments generated. For this study the apparatus was used to measure linear forces generated by the chains and no measurements were made of any moments produced.

The apparatus was loaded ten times at force levels of 100 grams and 200 gms using dead weight loading to determine variability inherent in the apparatus. Standard deviations of $\pm$0.324 gms and $\pm$0.561 gms respectively, were obtained. Variability inherent in the material was determined by measuring the force produced when a four loop length of chain was stretched to 20mm between two 1.6mm diameter stainless steel pins on the measuring apparatus. This was repeated for ten separate chains and the standard deviation was calculated at ± 9.70 gms.

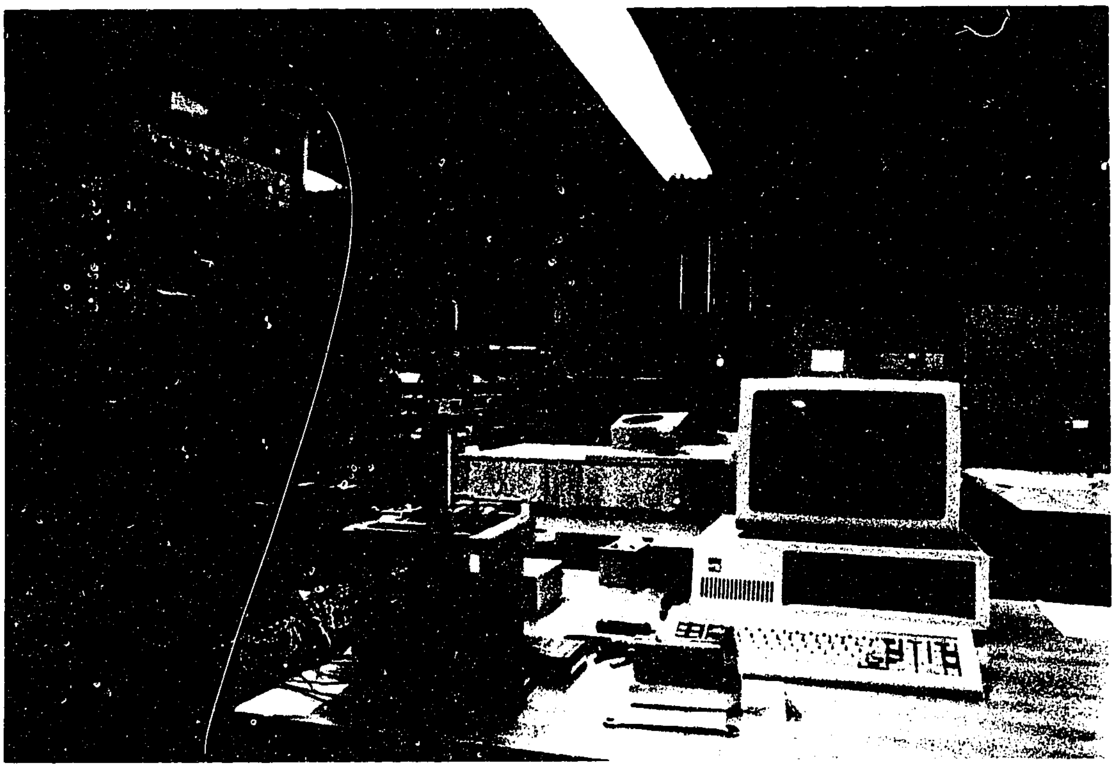

Figure 1. Force/Moment Measuring Apparatus.

ii. Bracket / Pin Assemblies

Three hundred sixty orthodontic brackets* were modified by placing a 1.6mm diameter, 16mm long stainless steel pin through the centre of the bracket base (FIG. 2a,2b). A friction fit ensured that the pin would not move within the bracket base. One half of the bracket/pin assemblies were then placed into a brass plate bearing a second pin (FIG. 3). The distance between the centre of the bracket and the centre of the second pin on the plate represented the distance between the second bicuspid bracket and the hook on a first molar band. The bracket/pin and bracket/pin/plate assemblies could now be placed in pin holding blocks (FIG. 4). These were constructed of acrylic resin, with holes drilled into the top of the blocks to allow the assemblies to be seated. The inter-bracket distance was adjustable and a stabilizing screw was placed in the middle of the blocks to minimize flexure.

c. DISTANCES USED

It was decided that distances appropriate to a simulation of cuspid retraction would be used. Measurements

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* pre-angulated, pretorqued edgewise bracket. Unitek Corporation, Monrovia, California

Figure 2. Bracket/Pin Assembly.

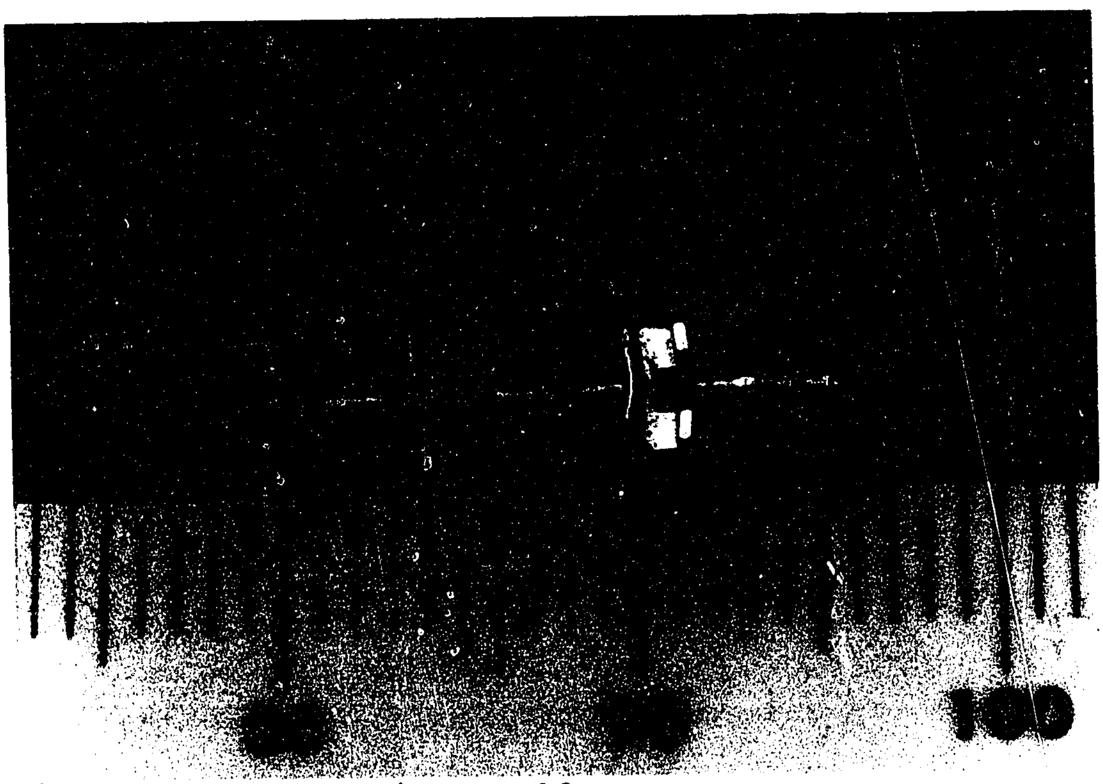

Figure 2a. Bracket/Pin Assembly.

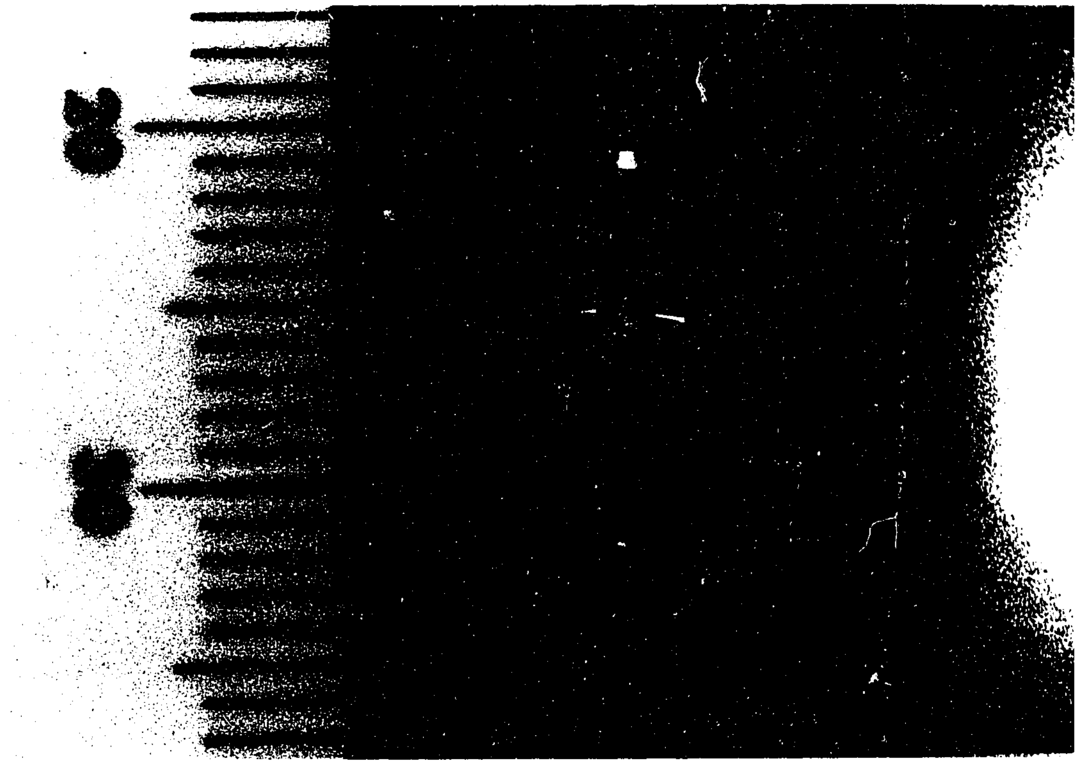

Figure 3. Bracket/Pin/Plate Assembly.

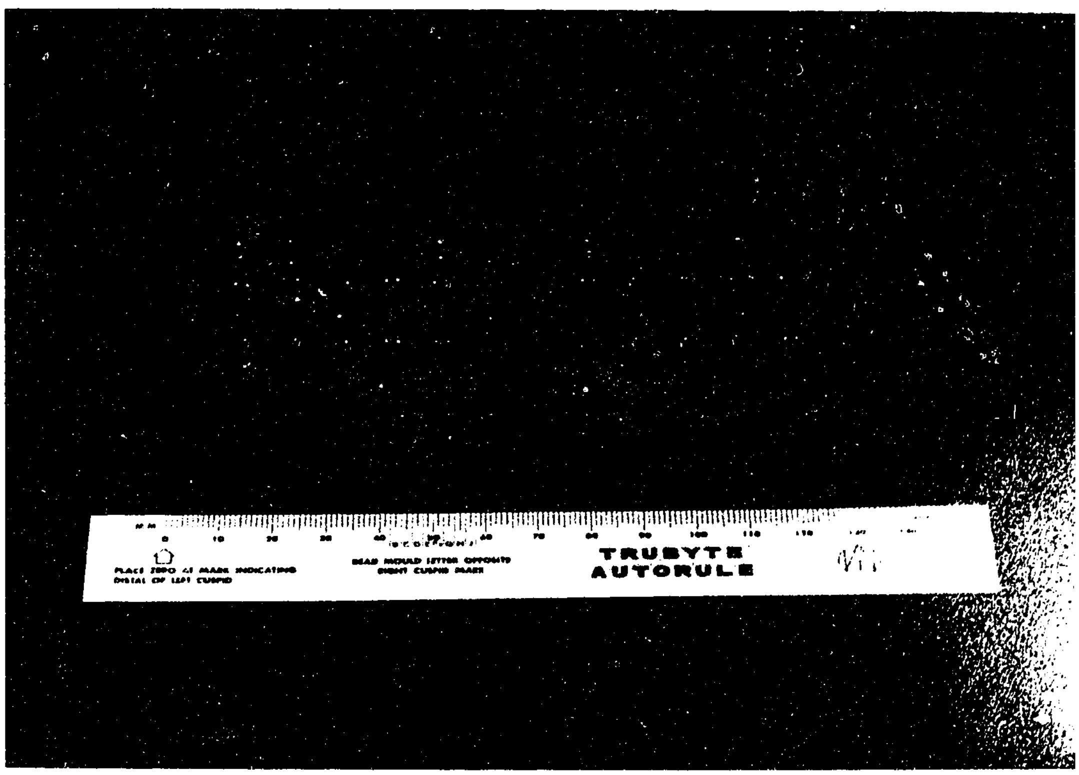

Figure 4. Pin Holding Block.

were made from pretreatment models of thirty consecutive cases treated by extraction of four first bicuspids at the University of Alberta graduate orthodontic clinic. All cases were in the permanent dentition, with no missing or grossly malformed teeth. The following measurements were made in each arch:

- distance from centre of mesiobuccal cusp of first molar to centre of buccal cusp on second bicuspid.
- distance from centre of buccal cusp of second bicuspid to centre of labial surface of cuspid.
- distance from centre of mesiobuccal cusp of first molar to centre of labial surface of cuspid.

These points were chosen to approximate the area of the hook on a first molar band and the centre of a bracket placed on the second bicuspid or cuspid.

Measurements were made with an electronic digital caliper* and were recorded to the nearest 0.01mm. Means and standard deviations for combined maxillary and mandibular measurements were calculated (APPENDIX 1). The

---

*MAX-CAL Electronic Caliper
Japan Micrometer Mfg. Co.,Ltd.
2-29, Uchikyuhoji-machi, Higashi-ku,
Osaka, 540 Japan

distances measured were;

- first molar to second bicuspid (6.9mm ± 0.95mm)
- second bicuspid to cuspid (15.7mm ± 1.43mm)

d. CONFIGURATION OF CHAINS

A pilot study was performed to determine the appropriate configuration of chain to be used. Previous studies of force decay had stretched the chains between two points[1-17]. When used clinically the chain is most often stretched over several brackets. In the case of cuspid retraction it is often placed on the first molar, the second bicuspid and then the cuspid with one loop free between the bicuspid and the cuspid (FIG 5a). In the pilot study, this configuration was compared to stretching the chain over the distance from first molar to cuspid directly (FIG 5b) and to stretching the chain from first bicuspid to cuspid directly (FIG 5c). The forces produced were measured using the force/moment measuring apparatus. It was determined that the groups were significantly different from each other ($p<0.05$). All subsequent tests were done with the chain stretched to simulate the configuration, first molar to second bicuspid to cuspid (FIG 5a). Four loop chains were used for all force decay testing. Both four loop and three loop chains were used for force/extension testing.

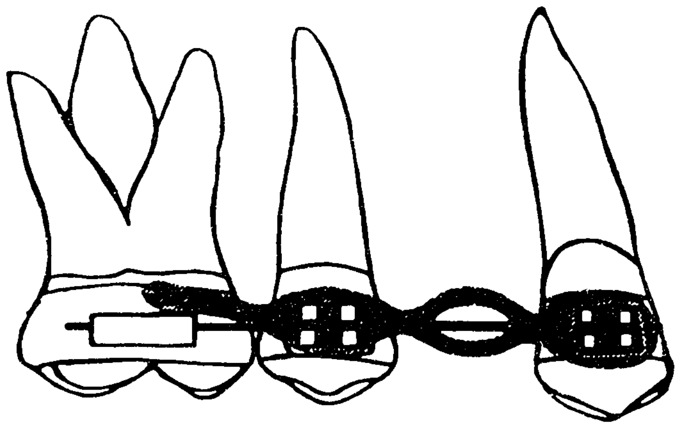

Fig 5a. Chain Configuration 6-5-3

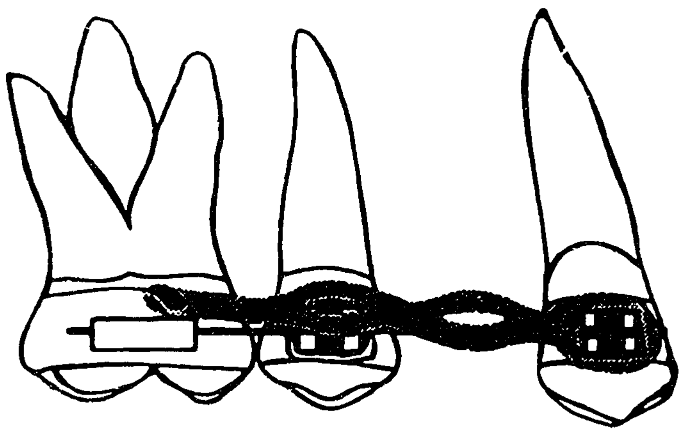

Fig. 5b. Chain Configuration 6-3
(Note - Bicuspid not engaged)

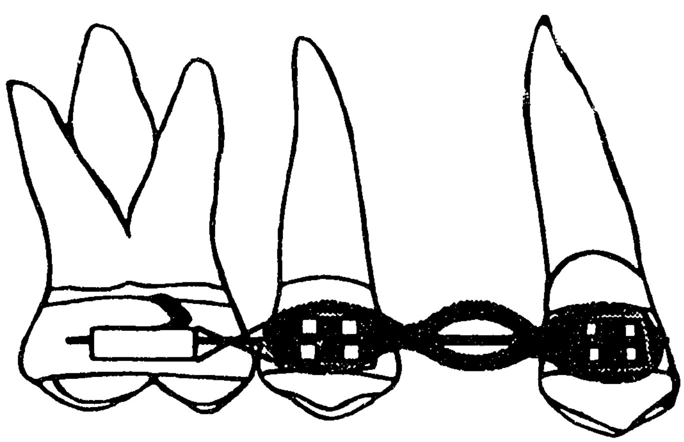

Fig. 5c. Chain Configuration 5-3

e. FORCE DECAY MEASUREMENT

i. Experimental groups;

CONTROL (Ctrl): tested as received from manufacturer.

PRESOAK (PS): chains soaked in room temperature water for one hour prior to the initial force levels being determined. Testing was done immediately upon removal from the water.

$40^{o}C$ PRESOAK (40PS): chains soaked in water at $40^{o}C$ for one hour prior to the initial force levels being determined. Testing was done immediately upon removal from the water.

CHEMICLAVE x 1 (Chem1): chains subjected to a single chemical vapor autoclave* sterilization.

---

*Harvey Chemiclave 6000
MDT Corporation
19645 Rancho Way
Rancho Dominguez
California, 90220

CONTROL 2 (Ctrl2): tested as received from manufacturer. This group was tested with groups 6, 7 and 8, four months after groups 1 thru 4. This second control group was included to determine the effect of shelf life on the material.

CHEMICLAVE x 4 (Chem4): chains subjected to four separate chemical vapor autoclave sterilizations. At least one hour was allowed between each sterilization to permit the chains to return to room temperature.

ETHYLENE OXIDE x 1 (EO1): chains subjected to a single ethylene oxide* sterilization.

ETHYLENE OXIDE x 4(EO4): chains subjected to four separate ethylene oxide sterilizations with at least 24 hours between each sterilization.

---

*AMSCO 2057 Gas Sterilizer/Aerator
American Sterilizer Company,
Erie Pennsylvania
16514 USA

Ethylene Oxide gas sterilization was chosen because it is the recommended means of sterilizing other rubber products such as prophy cups[21] and because it is used to sterilize elastomeric chains in the graduate orthodontic clinic at the University of Alberta. During a gas sterilization cycle materials are exposed to a mixture of ethylene oxide and dichlorofluoromethane at a temperature of 55°C for 1 hour and 45 minutes followed by a 12 hour aeration cycle.

Chemical vapor autoclave, being less expensive, less time consuming and more available to the practitioner was chosen as a second method to be investigated.

ii. Procedure

The bracket/pin assemblies were placed in the pin holders and the distance between bracket centres was set at 15.7mm. A four loop length of chain was then slowly stretched to engage the pin and the two brackets (FIG 6). The pin was then transferred to the force/moment measuring apparatus and the force measured and recorded. The bracket/pin/chain combination was then returned to its spot on the pin holding block. To ensure that the pins remained at the pre-set distance, and that the chains were not relaxed and then re-stretched each time a measurement was taken, adjustable transfer plates were used to deliver the bracket/pin/chain combination back and forth from the pin holding blocks to the measuring apparatus (FIG 7a,7b).

Measurements were taken and recorded for all 10 pins on each pin holding block. The blocks were then placed in water held at a constant temperature of 37°C. This was repeated after one hour, one day, one week, two weeks, three weeks and four weeks. Chains were returned to the constant temperature bath* immediately upon completion of each test.

Tooth movement at a rate of 0.25mm/week was simulated by adjusting the inter-bracket distance on the pin holding blocks. Adjustments were made on the third, tenth, seventeenth and twenty-fourth days after initial testing.

Means and standard deviations for each group at each time were calculated. Comparisons were made amongst experimental groups at any one test time using a single variant analysis of variance performed at $p<0.01$.

Relative force was calculated as a percentage of initial force. Means and standard deviations were calculated for each group at each time. Comparisons were made amongst experimental groups at any one test time using a single variant analysis of variance performed at $p<0.01$.

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*MGW Lauda Model T-1
Brinkmann Instruments
Rexdale, Ontario

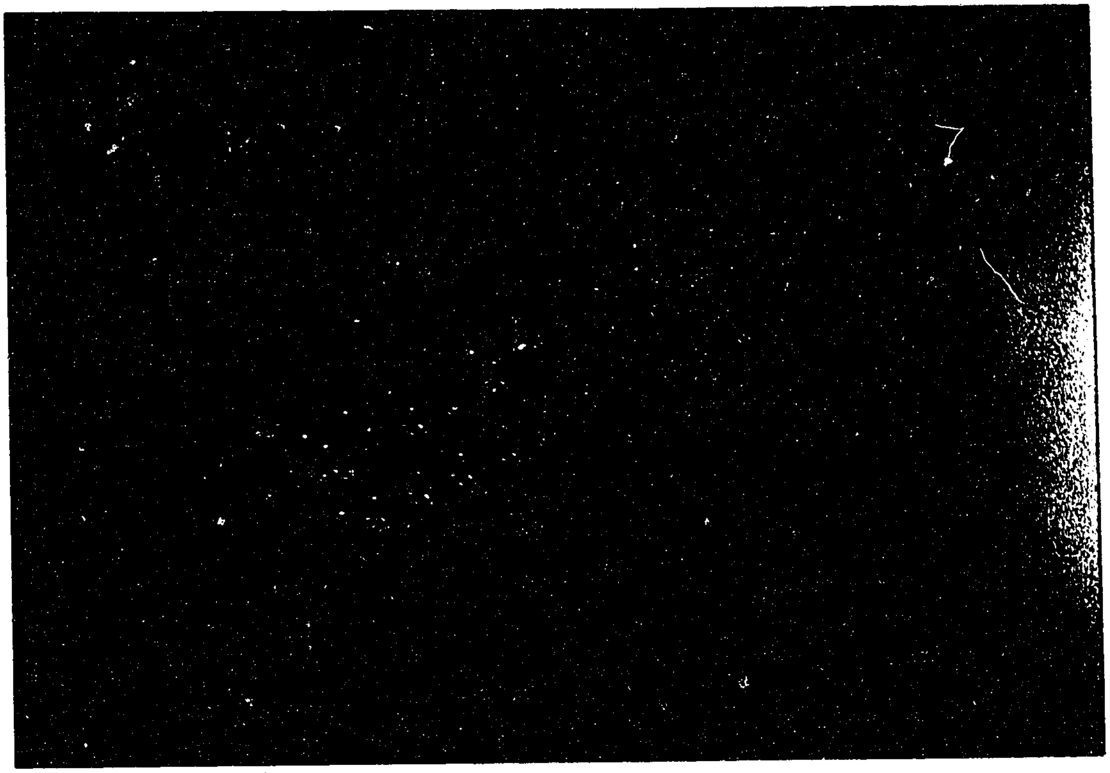

Figure 6. Chains on Holding Blocks.

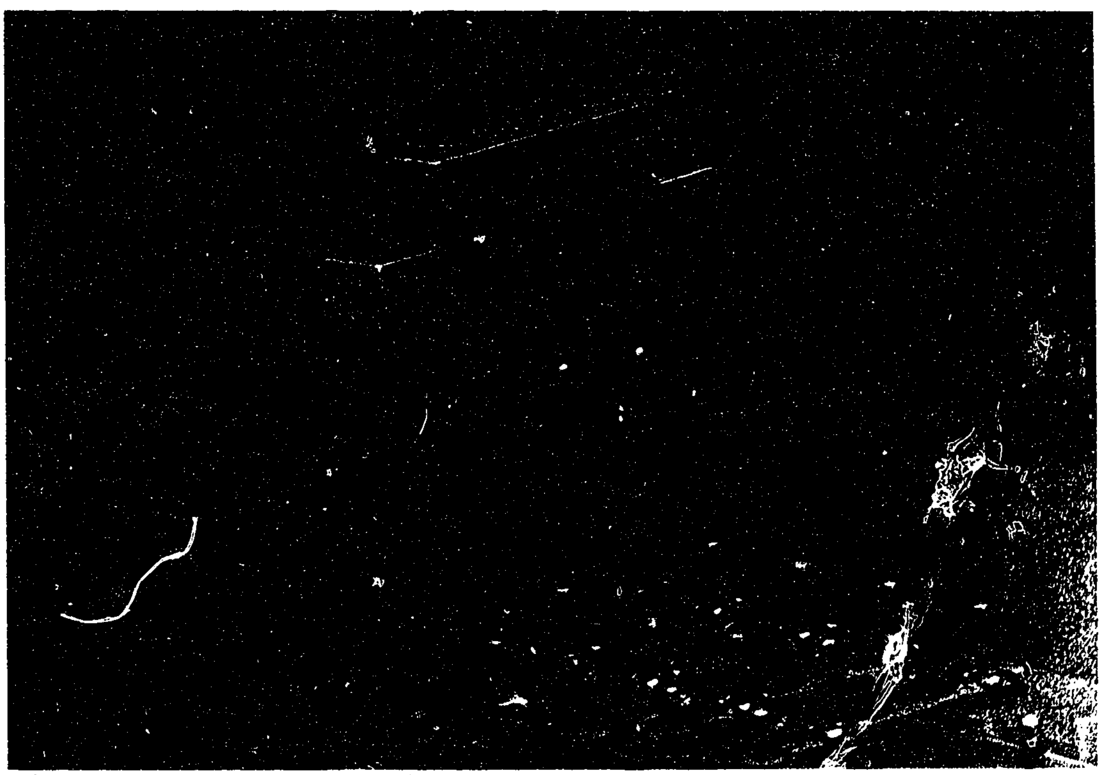

Figure 7a. Transfer Plates.

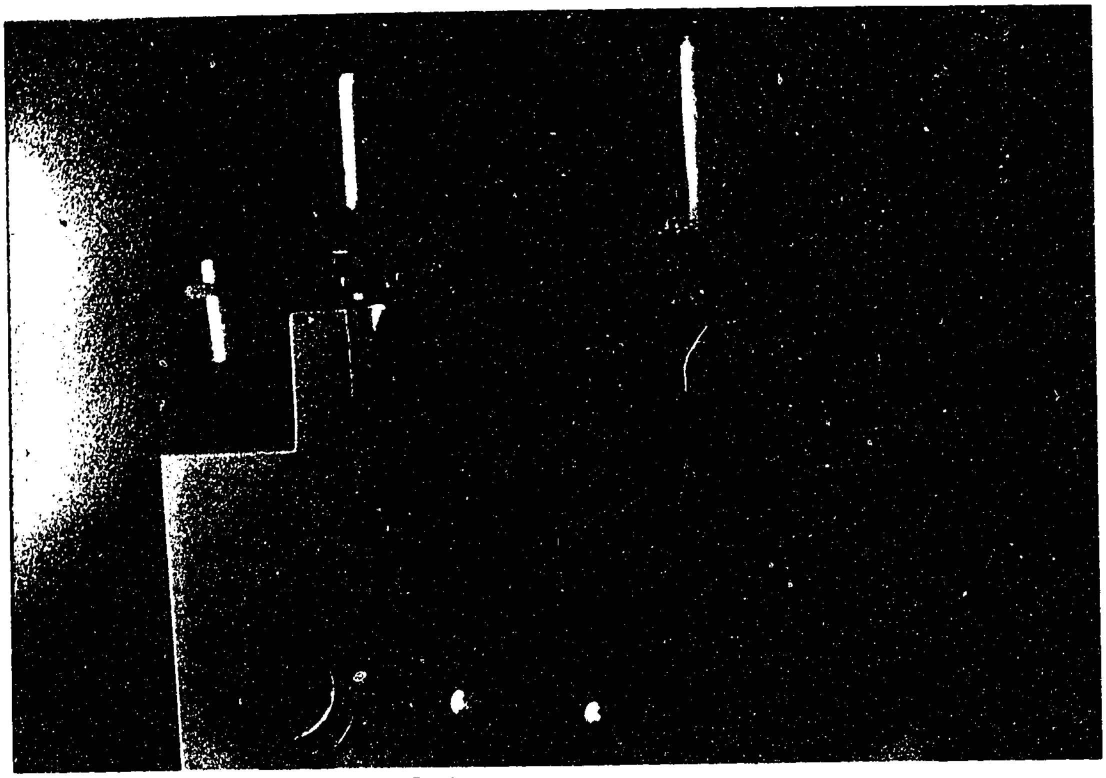

Figure 7b. Transfer Plates.

f. FORCE/EXTENSION MEASUREMENT

The interbracket distance on the force/moment measuring apparatus was set at the distance to be tested (Table 2). One end of the chain was placed on a pin/bracket assembly and the other on a pin/bracket/plate assembly with the "molar" pin and the "bicuspid" bracket engaged. For groups F to N one loop was left free between the "bicuspid" bracket and the "cuspid" bracket. Care was taken to not stretch the chain except to place it over the bracket tie wings. The chain was then placed directly on the measuring apparatus and the force generated was recorded. Note that the chain was stretched to place on the measuring apparatus and the force recorded within five seconds of placement, unlike the force decay tests where the chain was stretched on the pin holding block and then transferred to the measuring apparatus, the elapsed time between stretching and recording being approximately one minute.

A polynomial trend test was performed on the data to determine the degree of linearity between force produced and distance stretched.

Table 2 Force/Extension experimental groups

group	# loops	interbracket distance (bicuspid to cuspid)
A	3	6.5mm
B	3	7.5mm
C	3	8.5mm
D	3	9.5mm
E	3	10.5mm
F	4	9.5mm
G	4	10.5mm
H	4	11.5mm
I	4	12.5mm
J	4	13.5mm
K	4	14.5mm
L	4	15.5mm
M	4	16.5mm
N	4	17.5mm

IV. RESULTS:

a. CHAIN CONFIGURATION

When the three chain configurations were compared it was found that the chain configuraton 6-3 produced the highest force, followed by 5-3 and then 6-5-3 (Table 3). All groups were significantly different from one another $p<0.05$ (APPENDIX 2).

Table 3 Comparison of chain configurations
4 loop chain

group	distance (mm)	X ± S.D. (grams)
6-5-3	22.7	198.7 ± 11.1
6-3	22.7	278.8 ± 11.0
5-3	15.7	208.6 ± 10.9

The force level for the 6-5-3 group (198.7 gms.) is less than that produced by the control group (226.7) by about 12%. The material used in the chain configuration tests was not from the same manufacturers lot as that used in subsequent tests. Also no attempt was made to standardize the rate of stretch for the chain configuration tests with subsequent tests although within tests this was attempted.

b. FORCE DECAY

Comparison of force levels and of % initial force remaining were made at $p<0.01$.

Means and standard deviations for the force decay experimental groups are reported in Tables 3 and 4 and shown in Figs. 8 and 9. Force remaining as a percent of initial force is reported in Tables 5 and 6 and shown in Figs. 10 and 11. Raw data for all force decay experimental groups is found in Appendix 3.

Initial force for Ctrl (control) was 226.7 gms. This then showed a decay pattern similar to that reported in other studies, i.e. an initial rapid decay especially in the first 24 hrs. followed by a more gradual decay over the remaining weeks. After 1 day 113.6 gms (50.1% of initial force) remained and after four weeks 47.1 gms (20.7%) remained. This general pattern was followed for all groups.

The PS (presoak) and 40PS (presoak in $40^{o}C$) groups had significantly lower force levels at initial, 1 hr. and 1 day as compared to the control. Subsequent force levels were not significantly different. There was no significant difference in force levels between PS and $40^{o}PS$ at any of the test times.

Chem1 (single chemical vapor autoclave) had a larger variance than the control. The chains were measured after sterilization and were found to have shrunken in length by approximately 15% (Table 8). While initial force was significantly lower than the control, the force levels from 1 week to 4 weeks were significantly higher.

Table 4. Force levels (gms) X ± S.D.

group	initial	1h	1day	1wk	2wk	3wk	4wk
Ctrl n=28	226.7 ±10.43	145.7 ±8.75	113.6 ±11.37	73.8 ±7.60	67.9 ±5.96	55.8 ±5.59	47.1 ±6.93
PS n=29	* 188.4 ±10.35	* 125.4 ±7.24	* 97.8 ±8.25	69.1 ±4.86	65.6 ±4.83	58.2 ±5.78	44.5 ±5.03
40PS n=29	* 182.1 ±10.88	* 126.1 ±9.58	* 103.9 ±8.37	72.6 ±8.28	67.9 ±7.27	54.2 ±7.35	48.7 ±6.79
Chem1 n=30	* 216.8 ±18.88	141.4 ±11.38	118.5 ±8.83	* 94.8 ±10.97	* 83.5 ±12.50	* 62.9 ±8.08	* 57.2 ±7.18

- Single variant analysis of variance (Appendix 5)

* - significantly different from control $p<0.01$

Ctrl - control

PS - presoak 1 hour in room temperature water

40PS - presoak 1 hour in water at 40°C

Chem1 - chemical vapor autoclaved once

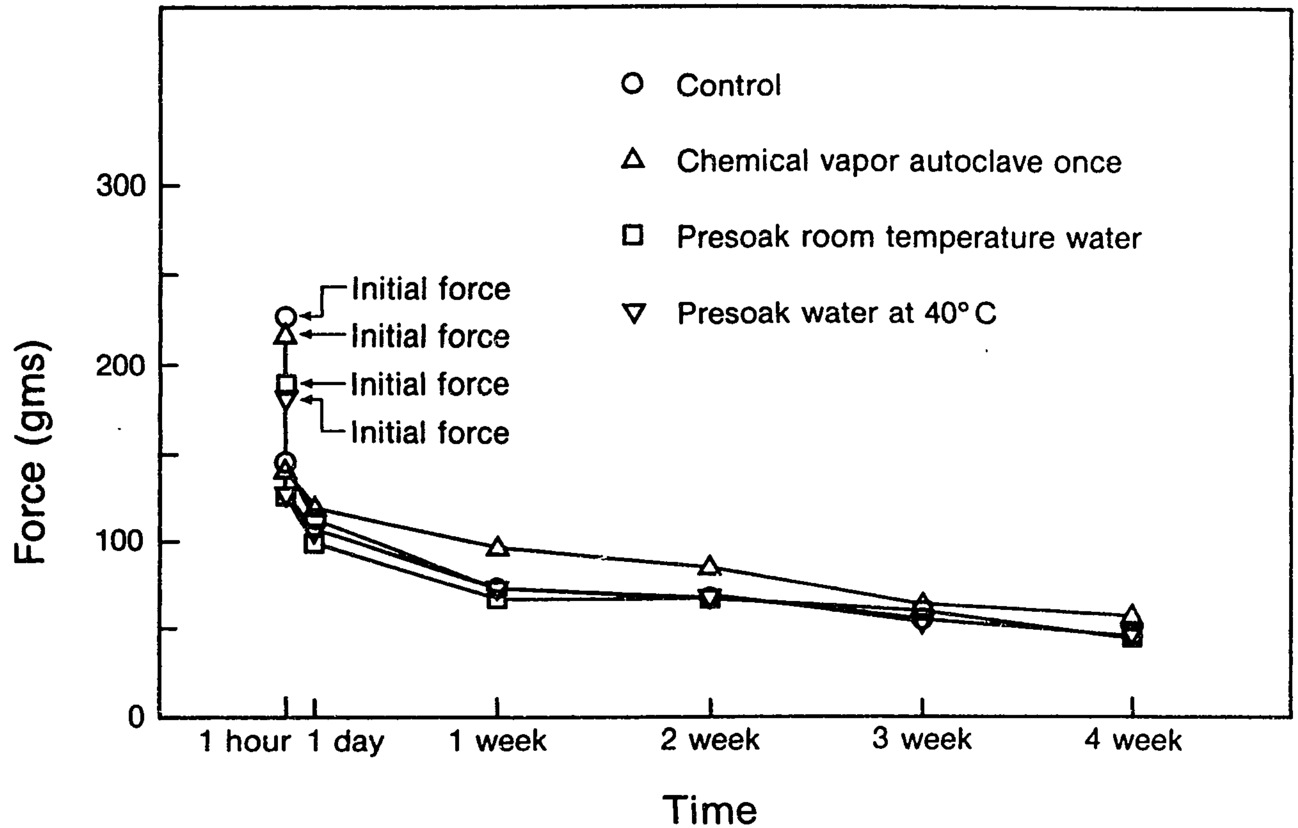

Figure 8. Force decay-control, chemical vapor autoclave once, presoak room temperature and presoak water at 40° C.

Table 5. Force levels (gms) X ± S.D.

group	initial	1h	1 day	1wk	2wk	3wk	4wk
Ctrl2 n=30	232.4 ±13.20	144.7 ±10.03	113.1 ±7.20	85.7 ±5.40	76.3 ±7.55	65.3 ±8.02	52.1 ±10.27
Chem4 n=30	* 213.5 ±16.39	150.9 ±11.08	* 126.9 ±9.49	* 102.0 ±9.59	78.9 ±9.25	68.6 ±8.93	52.6 ±9.48
EO1 n=30	* 253.7 ±11.31	* 180.2 ±7.61	* 144.0 ±7.65	* 119.0 ±6.70	* 98.9 ±7.15	* 87.2 ±9.93	* 71.8 ±7.37
EO4 n=30	* 255.1 ±12.38	* 174.3 ±6.53	* 144.6 ±7.12	* 120.4 ±6.52	* 99.6 ±5.96	* 88.7 ±6.42	* 71.1 ±6.83

- Single variant analysis of variance (Appendix 5)

* - significantly different from control2 $p<0.01$

Ctrl2 - second control

Chem4 - chemical vapor autoclaved four times

EO1 - ethylene oxide sterilization cycle once

EO4 - ethylene oxide sterilization cycle four times

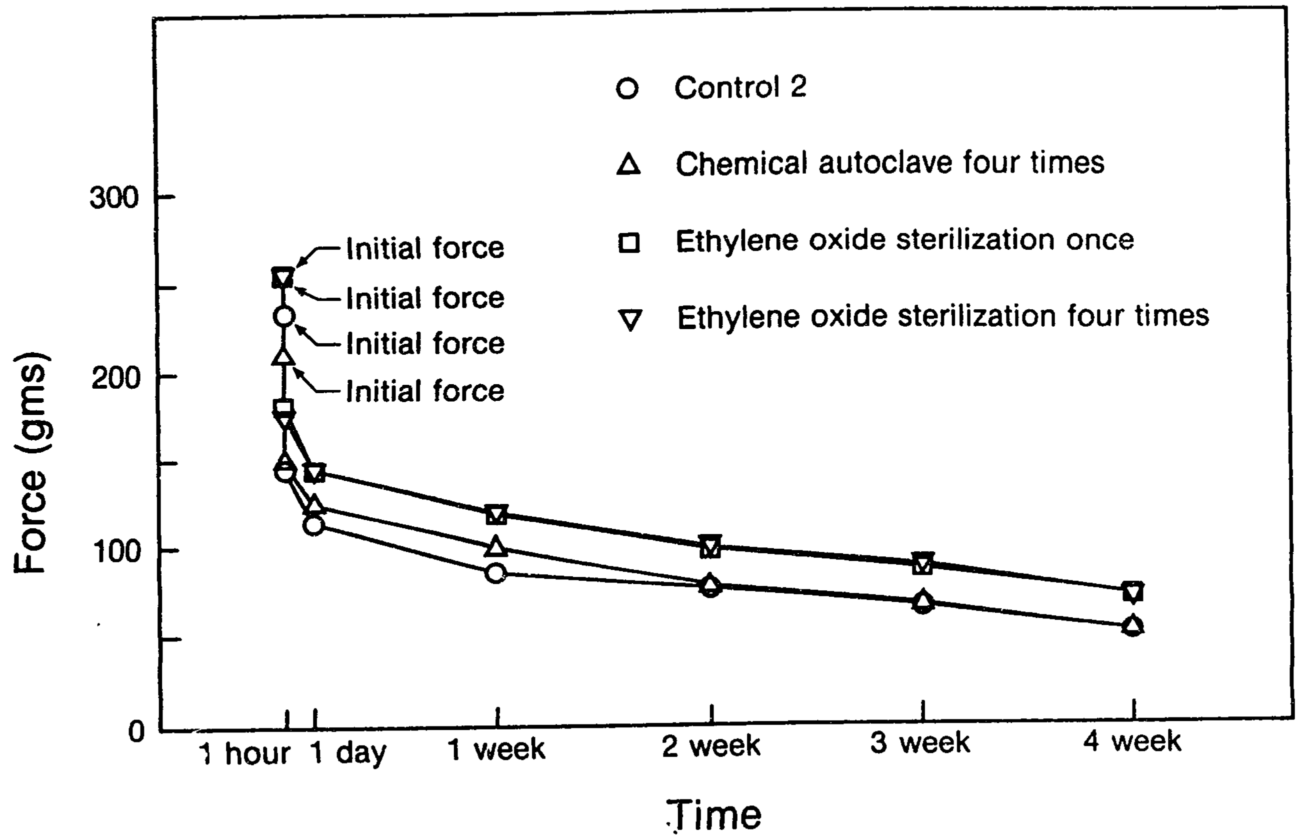

Figure 9. Force decay-control 2, chemical vapor autoclave four times, ethylene oxide sterilization once and ethylene oxide sterilization four times.

Table 6. Force levels (% initial force) X ± S D.

group	1h	1day	1w	2w	3w	4w
Ctrl n=28	64.3 ±3.79	50.1 ±4.39	32.6 ±2.85	30.0 ±2.23	24.6 ±2.34	20.7 ±2.70
PS n=29	66.6 ±3.17	51.9 ±3.52	* 36.7 ±2.49	* 34.9 ±2.49	* 30.9 ±2.74	* 23.6 ±2.41
40PS n=29	* 69.2 ±3.30	* 57.1 ±3.56	* 39.8 ±3.47	* 37.2 ±2.98	* 29.7 ±3.10	* 26.7 ±3.04
Chem1 n=30	65.3 ±3.12	* 54.8 ±3.48	* 43.8 ±4.12	* 38.5 ±5.02	* 29.1 ±3.26	* 26.4 ±3.02

- Single variant analysis of variance (Appendix 5)

* - significantly different from control p<0.01

Ctrl - control

PS - presoak 1 hour in room temperature water

40PS - presoak 1 hour in water at 40°C

Chem1 - chemical vapor autoclaved once

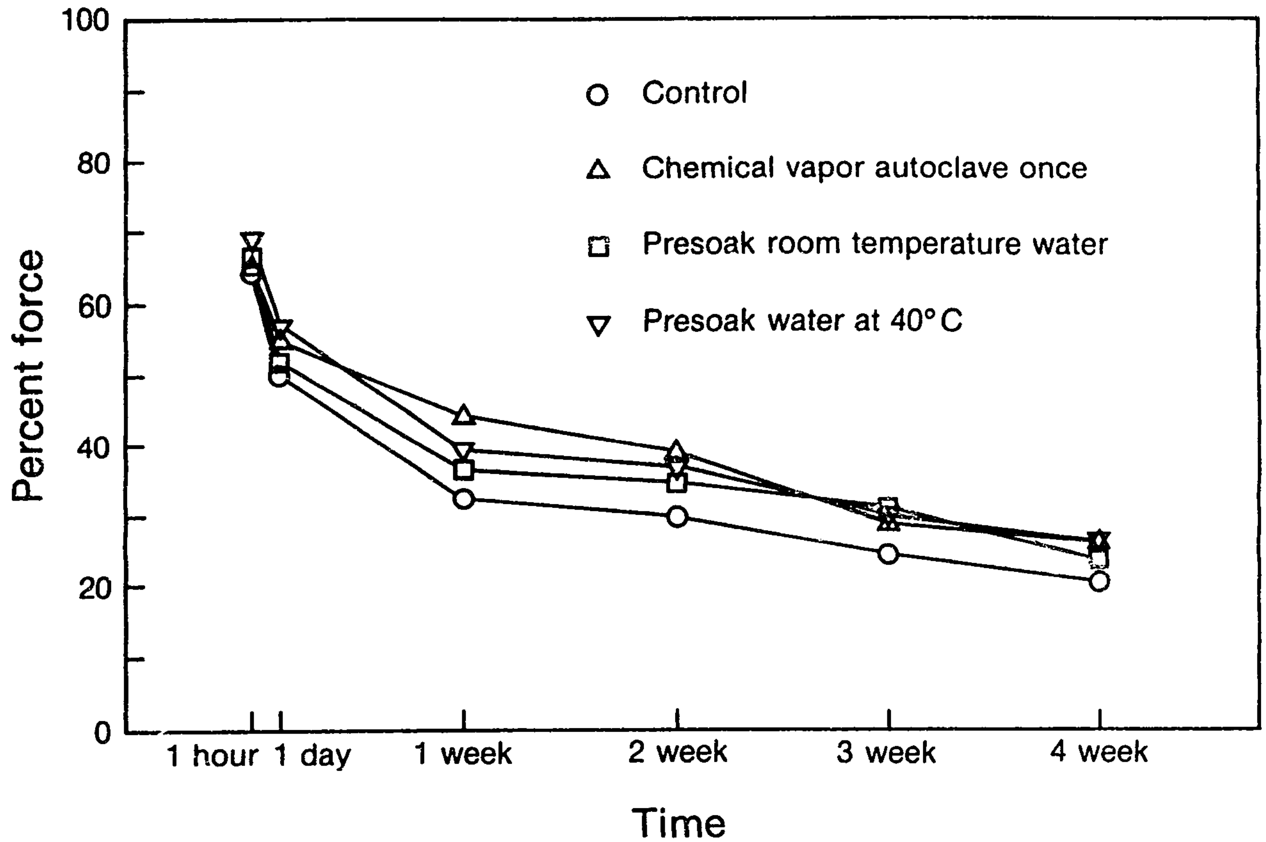

Figure 10. Percent of initial force remaining-control, chemical vapor autoclave once, presoak room temperature and presoak water at 40°C.

Table 7. Force levels (% initial force) X ± S D.

group	1h	1day	1wk	2wk	3wk	4wk
Ctrl2 n=30	62.4 ±4.64	48.8 ±3.12	36.9 ±2.33	32.8 ±2.74	28.1 ±3.39	22.4 ±4.32
Chem4 n=30	* 70.7 ±2.20	* 59.5 ±2.87	* 47.7 ±2.32	* 36.9 ±2.99	* 32.1 ±3.35	* 24.6 ±3.82
EO1 n=30	* 71.1 ±2.86	* 56.8 ±3.02	* 47.0 ±2.92	* 39.0 ±2.67	* 34.4 ±3.69	* 28.3 ±2.67
EO4 n=30	* 68.4 ±2.54	* 56.8 ±2.60	* 47.3 ±2.51	* 39.1 ±2.44	* 34.8 ±2.64	* 27.9 ±2.66

- Single variant analysis of variance (Appendix 5)

* - significantly different from control2 p<0.01

Ctrl2 - second control

Chem4 - chemical vapor autoclaved four times

EO1 - ethylene oxide sterilization cycle once

EO4 - ethylene oxide sterilization cycle four times

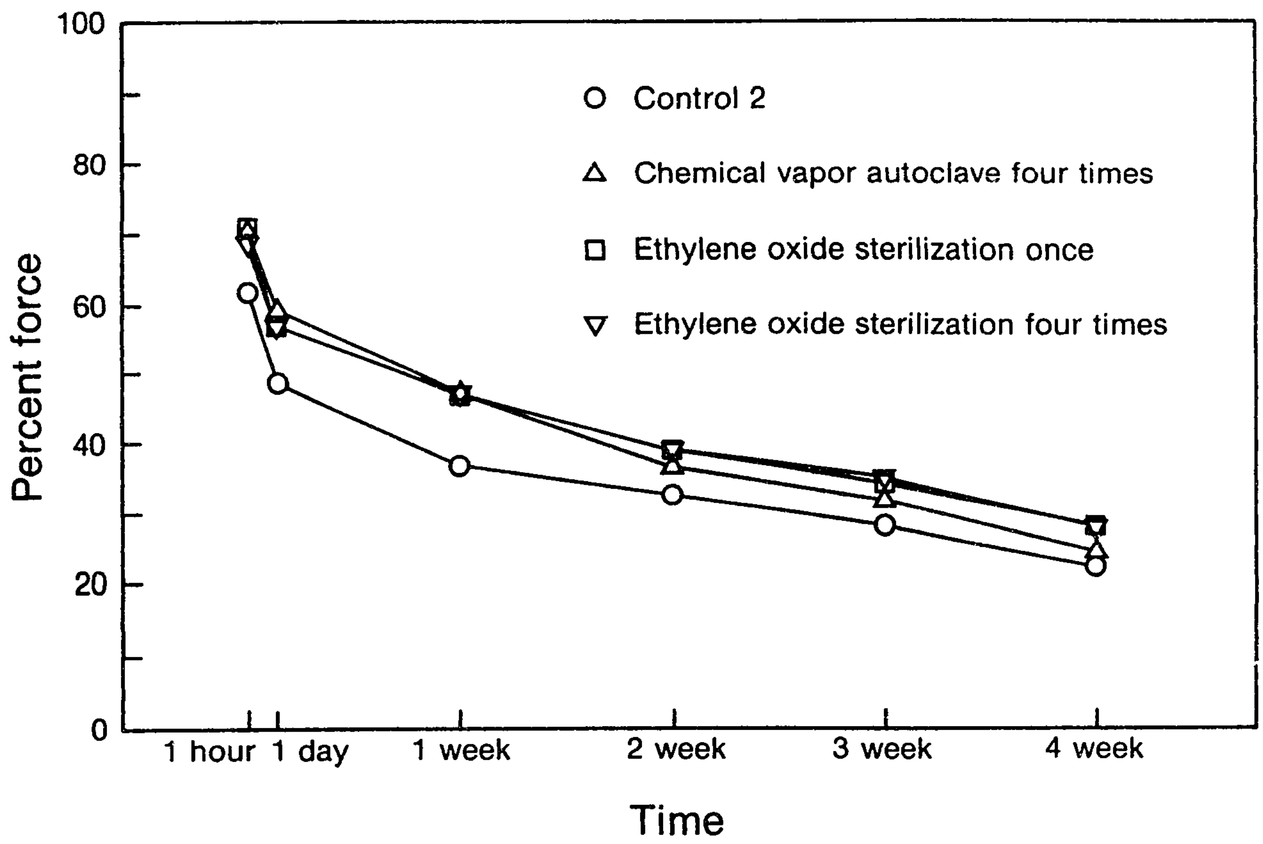

Figure 11. Percent of initial force remaining-control 2, chemical vapor autoclave four times, ethylene oxide sterilization once and ethylene oxide sterilization four times.

Table 8. Chain lengths (mm) X ± S.D.

group	chain length	% shrinkage
Ctrl	13.29 ±0.02	-
EO4	12.72 ±0.02	5%
Chem1	11.33 ±0.37	15%

Standard error of measurement ±0.01mm

A comparison of the two control groups (Ctrl and Ctrl2, Tables 9 and 10) showed no significant differences at initial, 1 hr., 1 day, or 4 weeks for actual force levels and for percent of initial force remaining. At 1, 2 and 3 weeks Ctrl2 generated higher forces (by approximately 10 grams) and the percent of initial force remaining was higher.

Table 9. Comparison Control and Control2 - force (gms)

group	initial	1h	1day	1wk	2wk	3wk	4wk
Ctrl	226.7 ±10.43	145.7 ±8.75	113.6 ±11.37	73.8 ±7.60	67.9 ±5.96	55.8 ±5.59	47.1 ±6.93
Ctrl2	232.4 ±13.20	144.7 ±10.03	113.1 ±7.20	* 85.7 ±5.40	* 76.3 ±7.55	* 65.3 ±8.02	52.1 ±10.27

(Single variant analysis of variance - Appendix 5)
* - significantly different p<0.01

Table 10. Comparison Control and Control2 - % initial force remaining.

group	1h	1day	1wk	2wk	3wk	4wk
Ctrl	64.3 ±3.79	50.1 ±4.39	32.6 ±2.85	30.0 ±2.23	24.6 ±2.34	20.7 ±2.70
Ctrl2	62.4 ±4.64	48.8 ±3.12	* 36.9 ±2.33	* 32.8 ±2.74	* 28.1 ±3.39	22.4 ±4.32

(Single variant analysis of variance - Appendix 5)
* - significantly different $p<0.01$

Ctrl2, Chem4 (chemical vapor autoclave four times), EO1 and EO4 (ethylene oxide sterilization once and four times respectively) were tested 4 months after the first four groups. Because there were some differences between the two control groups, these last groups were compared to each other only.

Initial force level for Chem4 was lower than for its control. At 1 hr. there was no significant difference. At 1 day and 1 week this group delivered higher force levels but subsequent to this were no significant differences from the control.

Force levels for EO1 and EO4 were significantly higher than the control at all test times. Chain shrinkage was approximately 5% (Table 8). Both groups retained a higher percent of initial force than Ctrl2 throughout the test period. No significant differences were found between EO1 and EO4.

c. FORCE/EXTENSION

Means and standard deviations for the forces produced at the various stretch distances are reported in Table 11 and presented in Figure 12. Raw data for all force/ extension experimental groups is reported in Appendix 4.

Table 11. Force produced at various extensions (gms) X ± S.D.

distance (mm)	4 loop chain	3 loop chain
6.5		119.7 ± 11.1
7.5		200.7 ± 11.9
8.5		292.5 ± 9.4
9.5	54.8 ± 6.7	355.5 ± 12.2
10.5	117.9 ± 8.9	392.2 ± 11.4
11.5	162.7 ± 9.9	
12.5	200.2 ± 11.1	
13.5	243.5 ± 7.5	
14.5	267.2 ± 11.6	
15.5	295.2 ± 12.9	
16.5	347.3 ± 14.1	
17.5	371.1 ± 6.6	

The 3 loop chain delivered 119.7 ±11.1 gms. at 6.5mm and this rose to 392.2 ±11.4 gms. at 10.5mm. Statistical

Force / Extension
3 & 4 - Loop Chains

Mean +/- Standard Deviation

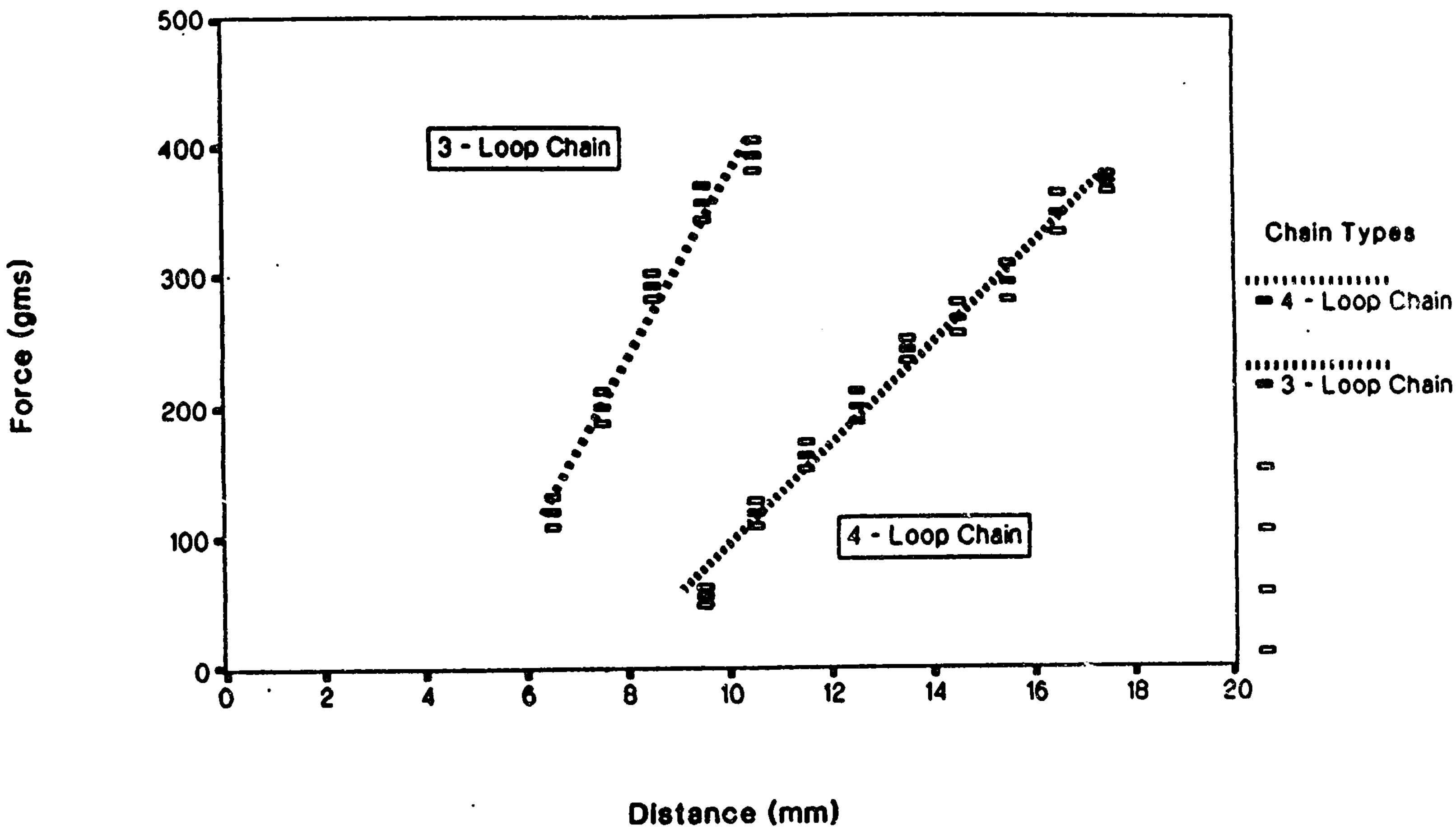

Figure. 12

analysis showed that a simple linear relationship between distance stretched and force generated accounted for approximately 98% of the variance in forces measured (APPENDIX 6). For every millimetre extended between 6.5mm and 10.5mm the three loop chain produced an additional 70 gms of force.

The 4 loop chain delivered 54.8 ±6.7 gms. at the minimum stretch tested (9.5mm) and 371.1 ±6.6 at the the maximum (17.5mm). In this case a simple linear relationship between distance and force accounted for approximately 99% of the variance in force (APPENDIX 6). For every millimetre of extension between 9.5mm and 17.5mm the four loop chain produced an additional 39.4 gms of force .

V. DISCUSSION:

a. CHAIN CONFIGURATION

The differences amongst the three configurations of chains tested are of interest. When the chain was stretched a given distance between two teeth (6-3) the force produced was considerably higher (80 gms.) than when other teeth were engaged by the chain within the same distance (6-5-3). An explanation for this may be found by looking at the distance stretched per unit length of chain and accepting that when the chain is used as in 6-5-3, the forces generated between the molar and the bicuspid will be equal in magnitude and opposite in direction. These forces will then effectively cancel each other out, leaving the force generated between the bicuspid and the cuspid. The stretch per unit length of chain (one loop) can then be calculated as follows;

group	# loops effective	effective distance	stretch per loop
6-5-3 & 5-3	3	15.7 mm	15.7/3 = 5.2mm/loop
6-3	4	22.7 mm	22.7/4 = 5.7mm/loop

In effect the chains in the 6-3 group were being stretched farther.

The 6-5-3 and the 5-3 groups showed a difference which was statistically significant ($p<0.05$). However the actual difference (approximately 10 grams) was about equal to the method error (± 9.7 grams) as described earlier.

Previous in vitro studies tested chains stretched between two points[1,4-19]. Force levels indicated by these studies cannot be applied to a clinical situation where the chain is employed in some other manner. Clinicians must be aware that how the chain is applied may be as important as the distance the chain is stretched or the length of chain used.

b. FORCE DECAY

In one group (Ctrl) two chains slipped from the pin holders and in two others (PS and 40PS) two chains slipped from the pin holders. No testing was done for these chains and sample size for these groups was reduced to 28, 29 and 29 respectively.

i.Force Decay Pattern

The general pattern of force decay was similar to that reported in other studies[1,4-13,18]. This pattern of rapid initial decay followed by a gradual decay over the next few weeks may necessitate the use of high initial forces or result in inadequate forces at some time between appointments. Three of the experimental groups showed some improvement over the control group in this regard. Force levels for PS and 40PS were lower for the first day and then were the same over the remaining weeks. These groups were soaked in tap water (at room temperature and 40°C respectively) for one hour prior to testing. Non-covalent bonds between molecules and within a molecule are present in elastomeric materials. Huget et.al.[16] believed that water molecules would displace these inter- and intra-molecular hydrogen bonds. This would have the effect of allowing chain slippage to occurr more easily. Pre-soaking would cause the material to become "plasticized" in this manner resulting in the decreased initial force found with the PS and 40PS groups. By keeping a few chains in sterile water at chairside, the clinician may be able to address, at least partly, the problem of high initial forces. Room temperature water is suggested because 40PS showed no advantages over PS.

Cheml also offered some improvement in the pattern of force decay. The initial force was significantly lower than the control and the force remaining from 1 week to 4 weeks was higher. However one must consider that this group showed a larger variance than Ctrl. Consistency in force delivery is therefore suspect. The higher variance seen is explained by the shrinkage of the chains during the sterilization cycle since some chains shrank more than others.

Ctrl2 retained a higher percentage of initial force at weeks 1, 2 and 3. The differences were small but statistically significant. At 4 weeks there was no difference. It is difficult to explain this behaviour. One would expect that any effect that the four month shelf life had on the material would have been seen throughout the entire test period. The difference in force was small (on the order of 10 grams). This small difference, and the fact that the forces after 4 weeks were not significantly different would suggest that in clinical use a shelf life of this length does not adversely affect the material.

Both groups subjected to Ethylene Oxide sterilization produced higher forces throughout the four weeks. In addition they retained a higher percentage of initial force throughout this period. The higher initial forces generated would not be a problem clinically since they are within the range needed for tooth movement. The fact that a higher percent of initial force was retained would allow one to leave the chain in place longer and still be confident that a force sufficient for tooth movement was being generated. Although some chain shrinkage did occur, it was small (5%) and uniform, therefore consistency of force delivery did not appear to be a problem.

Since the EO1 and EO4 groups behaved almost identically, one can suggest that multiple (at least four) sterilizations of the material by Ethylene Oxide gas will not adversely affect its force decay properties.

ii. Magnitude of Forces

While there is no clear consensus as to the threshold force needed to initiate tooth movement, the optimum force levels fall in the range of 100 to 300 gms (Table 1). For the purposes of this study these were accepted as the range within which tooth movement would optimally occur, while recognizing that at forces above and below this range the tooth could still move.

None of the groups delivered a force above 300 gms. All groups delivered initial forces above 100 gms. At 1 week Ctrl, PS, 40PS, Chem1 and Ctrl2 had all fallen below 100 gms. At 2 weeks Chem4 was also below 100 gms. The remaining two groups maintained force levels very near 100 gms at 2weeks (EO1 98.9 $\pm$7.15 gms. and EO4 99.6 $\pm$5.96 gms.). Under the conditions tested, in order to maintain a force of 100 gms. over four weeks, the initial force would have to be approximately 500 gms for the Ctrl group. Alternatively a chain with a smaller initial force could be used and then replaced before four weeks (these data would indicate that for the control groups the chain would have to be changed within one week).

Under clinical conditions one would have to consider all the factors that affect tooth movement, the force decay pattern of the chain, the force/extension characteristics of the chain, and the fact that decay occurrs more rapidly in vivo than in vitro[9,14,19], before deciding when the chain should be replaced. Some of the factors affecting tooth movement are under the control of the clinician while others are not. Differences in the cellularity of the PDL and its ability to respond to pressure or tension by resorbing or depositing bone cannot be influenced by the clinician. It should however be recognized that cellularity generally decreases with age[20] and forces would have to be applied for longer periods of time in order to accomplish tooth movement. Likewise the size and number of roots is not under the clinicians control. This information can be used however in developing anchor units and when deciding whether to move teeth individually or en masse. The remaining factors are all to some extent controllable. The type of force can be altered by choice of appliance (e.g. fixed or removable). Friction inherent in the appliance and force decay of the appliance are influenced by appliance design and choice of materials. The operator has some control over the type of tooth movement attempted. Tipping movements will require relatively less force as compared to bodily movements. The force levels referred to in Table 1 include both tipping and bodily movements of teeth. It should be recognized that within the range of f noted above (100gms. - 300 gms.) the lower end of the range is sufficient to tip teeth while the upper end will move teeth bodily.

c. FORCE/EXTENSION

The linear relationship between force produced and distance stretched allows the clinician to determine the magnitude of force generated upon chain placement. This is only accurate when the chain is used in a manner similar to that tested (i.e. 6-5-3) and over similar distances. Other authors have found a non-linear relationship. Ware[6] shows a linear relationship up to about 400 gms. The curve then became less steep until the force exceded 1000 gms. whereupon it once again became linear. Rock et.al[18] had similar findings with the "transition period" occurring from about 400 gms. to about 600 gms. The linear relationship found in this study is not inconsistene with previous findings since force levels did not excede 400 gms. in any of the experimental groups.

When using elastomeric chain the force/extension characteristics and the decay rate must both be considered. Given a force loss of approximately 80%, an initial force of 500 gms. is required to maintain at least 100 gms over four weeks. The chains tested did not deliver a force this high. If one is to use the chains at these distances then it would be necessary to change them before four weeks. At three weeks the force loss is approximately 75%. An initial force of 400 gms would leave 100 gms. after 3 weeks. The four loop chain did not deliver this force at any of the distances tested. One could then suggest that the chain would be most effective at distances greater than 17.5mm if left for periods of three weeks or longer. If used at distances smaller than this then the chain would have to be changed more often. The three loop chain delivered very close to 400 gms at 10.5mm. It would be expected to deliver effective forces for three weeks. At distances smaller than this, it too, would require more frequent changes.

Another option would be to place a second chain. The cuspid could then be retracted by a chain placed 6-5-3 on the facial side and another placed 6-3 on the lingual or palatal side. At a distance of 15.7mm one would expect the second chain to deliver a force of approximately 275 gms. on initial placement. This would bring the total force to near 500 gms. and will result in a force of near 100 gms after four weeks. The initial force of 500 gms. would decay to about 320 gms. in the first hour and about 250 gms in the first day. These forces would probably not be sufficient to cause hyalinization of bone adjacent to the tooth on the pressure side. Reitan [29] suggests that it akes "a few hours" for the initial histologic changes ssociated with hyalinization to become evident and 5 to 6 ays of excessive forces before "the periodontal fibres are ompressed enough to produce a standstill of the ooth"[29].

As space closes during cuspid retraction the clinician ill at some point change from a chain that has a free loop etween the second bicuspid and the cuspid (the four loop hain tested) to one that does not (the three loop chain ested). The data presented here indicates that when the istance (between bicuspid and cuspid) is near 17.5mm a our loop chain (used singly) should be changed at sometime etween two and three weeks. At distances less than this he chain is not likely to deliver a force of more than 100 ms over three weeks. When the space remaining is near 0.5mm a three loop chain can be used but it too should be hanged after three weeks. For distances below 17.5mm these ata indicate that the four loop chain alone will not eliver sufficient force over three weeks. Further nvestigation is required to determine the force/extension haracteristics of the three loop chain at distances over 0.5mm.

. LIMITATIONS of the STUDY

This study investigated one type of elastomeric chain rom one manufacturer and conclusions drawn are valid for this brand of chain only. In addition the test conditions are very specific with regard to chain configuration, and rate of tooth movement. The intra-oral environment was not reproduced. Such things as temperature fluctuations, the effect of salivary enzymes, chemicals found in foods and differing pH values could all be expected affect the material.

The linear relationship between force produced and distance stretched is valid only within the distances tested. The relationship above or below these distances was not determined.

e. SUGGESTIONS FOR FURTHER STUDY

A product comparison study would be of interest to compare the force decay and force/extension characteristics of the chain used here with other commonly used elastomeric chains.

The force extension characteristics of the chain at distances greater then those tested here would provide data to allow the development of a protocol for chain use when retracting cuspids.

Elastomeric chains are used in a wide variety of clinical situations. This study has attempted to investigate a simulation of cuspid retraction. Further studies are required to determine the forces generated at each point along the chain when it is used in other ways.

VI. CONCLUSIONS:

1. Sterilization of one brand of orthodontic elastomeric chain by ethylene oxide gas resulted in higher forces generated and a decreased rate of force decay. Repeated sterilizations (four times) produced the same effect as a single sterilization.

2. A single sterilization of one brand of orthodontic elastomeric chain by chemical vapor autoclave resulted in chain shrinkage, a less consistent delivery of force and a reduced force decay.

3. Repeated sterilization (four times) of one brand of orthodontic elastomeric chain by chemical vapor autoclave resulted in a reduced initial force and a reduced rate of decay.

4. Presoaking one brand of orthodontic elastomeric chain in room temperature water for one hour resulted in a decreased initial force. The decay rate was reduced during the one week to four week period. Force levels sufficient to move a tooth over a four week period were not maintained.

5. Presoaking one brand of orthodontic elastomeric chain in water at 40°C for one hour resulted in a decreased

initial force. The decay rate was reduced throughout the test period. Force levels sufficient to move a tooth over a four week period were not maintained.

6. A shelf life of four months had little effect on the force decay properties of one brand of orthodontic elastomeric chain.

7. Under the conditions tested the relationship between distance stretched and force produced was linear.

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VIII. APPENDICES:

APPENDIX 1

Measurements from 30 cases treated by extraction of four first bicuspids.

	max. & mand 6to5	max. & mand. 5to3
Mean (mm)	6.9	15.7
Standard Deviation (mm)	± 0.95	± 1.43
Range	5.14 to 10.96	11.31 to 19.45

APPENDIX 2

Pilot Study on Chain Configuration

	Group		
	6-5-3	6-3	5-3
Mean (mm)	198.7	278.8	208.6
Standard Deviation (mm)	± 11.1	± 11.0	± 10.9
Range	180.2 to 222.4	262.6 to 299.1	177.2 to 227.3

Comparison of Chain Configuration
Univariate Analysis of Variance

Univ Group	SSH	SSE	MSH	MSE
	114492.57	10528.05	57246.28	121.01
	F-RATIO	DFH	DFE	PROB
	473.06	2.0	87.0	.179E-46

$p<0.05$

6-5-3 n=30 X=198.7				
5-3 n=30 X=208.6	req. diff. obs. diff. S.E. D.F. Scheffe	7.07 9.97 2.84 87.00 2.49		
6-3 n=30 X=278.8	req. diff. obs, diff. S.E. D.F. Scheffe	7.07 80.15 2.84 87.00 2.49	7.07 70.18 2.84 87.00 2.49	
		6-5-3	5-3	6-3

APPENDIX #3

Control force (gms)

chain#	initial	1h	1d	1w	2w	3w	4w
1	241.8	141.7	115.1	76.4	68.6	54.5	48.4
2	229.4	129.3	121.2	84.3	62.1	50.8	42.3
3	241.7	147.4	119.0	80.5	69.5	55.2	50.5
4	240.0	142.5	111.8	66.2	63.3	59.1	44.1
5	227.9	154.0	124.6	84.7	73.3	57.8	54.0
6	231.0	149.2	110.5	74.4	69.1	51.8	42.1
7	233.8	146.9	112.2	76.7	68.9	53.3	44.9
8	215.8	129.5	95.3	66.9	62.7	47.6	34.2
9	214.8	131.2	100.5	68.3	65.8	44.7	35.7
10	222.3	143.2	114.9	73.2	72.6	47.3	43.3
11	233.2	156.3	121.1	77.5	73.5	56.4	50.4
12	225.8	155.2	124.2	67.0	64.6	54.4	46.5
13	236.7	152.2	124.7	76.8	74.4	62.0	57.2
14	244.1	159.3	129.6	86.5	84.1	60.0	57.3
15	235.5	159.2	121.6	84.2	77.1	66.4	59.5
16	231.9	152.3	120.7	80.2	71.2	64.4	57.1
17	231.4	152.1	134.8	79.0	72.0	65.9	59.8
18	223.3	157.7	137.6	87.5	76.6	64.7	56.3
19	231.7	147.2	106.5	76.2	67.8	53.2	41.5
20	217.1	142.1	102.4	65.7	62.2	56.8	43.7
21	223.5	140.0	96.4	64.1	63.8	60.6	46.6
22	213.3	134.7	103.4	60.6	59.1	49.1	42.7
23	218.7	139.6	107.4	74.5	67.1	54.3	45.9
24	235.8	141.7	103.5	64.6	60.3	52.5	38.5
25	218.7	138.0	96.1	64.4	61.1	51.5	45.0
26	207.3	135.4	100.6	66.5	61.3	53.3	40.5
27	205.2	152.5	111.5	71.2	68.1	58.7	45.3
28	215.7	148.5	114.7	68.8	61.5	55.7	44.9
Mean	226.7	145.7	113.6	73.8	67.9	55.8	47.1
std dev	10.43	8.75	11.37	7.60	5.96	5.59	6.93
range	205.2 to 244.1	129.3 to 159.3	95.3 to 137.6	60.6 to 87.5	59.1 to 84.1	44.7 to 66.4	34.2 to 59.8

note: chain #15 & 16 slipped off pin/bracket assembly
Data for these chains not entered
n=28 for this group

CHEM1

chain#	initial	1h	1d	1w	2w	3w	4w
1	189.3	128.1	111.1	99.3	86.4	62.3	48.0
2	236.6	152.8	132.6	112.6	99.0	81.6	76.0
3	198.8	122.6	110.3	99.4	89.5	55.8	52.9
4	220.4	142.7	114.6	106.9	97.1	69.0	54.0
5	238.0	153.5	117.4	99.7	96.6	59.1	56.0
6	227.9	133.7	108.7	97.8	85.5	58.7	54.3
7	198.7	135.9	113.1	101.8	96.8	58.5	53.1
8	239.4	154.7	130.0	118.0	110.6	85.4	70.0
9	267.0	168.4	132.5	108.0	104.7	70.9	57.7
10	240.0	149.5	127.7	103.4	95.9	68.6	60.0
11	238.9	144.9	117.4	98.9	88.7	61.2	54.8
12	233.1	146.7	119.0	94.7	80.1	52.1	50.1
13	218.6	137.3	111.1	94.9	88.8	58.3	53.2
14	189.7	124.5	115.9	82.3	80.6	64.6	60.5
15	235.0	152.8	130.7	101.4	91.7	66.1	65.4
16	218.0	137.9	121.9	87.6	85.8	62.5	60.3
17	217.5	143.0	122.1	91.6	88.4	62.5	60.4
18	195.2	128.4	98.2	84.2	76.4	58.9	48.1
19	199.8	128.8	106.3	79.3	77.0	53.2	49.5
20	218.4	138.4	125.6	93.4	82.0	72.2	68.8
21	223.4	150.6	127.8	96.5	68.5	62.8	58.7
22	220.1	162.6	130.5	106.7	83.7	72.9	68.8
23	215.5	139.5	128.6	99.0	65.5	63.9	60.1
24	208.5	148.2	119.7	100.9	71.8	65.5	61.1
25	212.3	139.3	116.1	91.4	69.9	48.5	44.4
26	187.4	119.7	105.0	85.8	83.0	50.4	47.3
27	206.4	137.2	119.8	81.7	67.6	58.9	55.3
28	185.4	131.3	109.5	72.2	65.5	58.3	55.4
29	210.6	145.0	116.5	81.1	65.8	63.7	56.7
30	213.6	142.9	116.0	73.8	61.1	60.3	54.8
mean	216.8	141.4	118.5	94.8	83.5	62.9	57.2
std dev	18.88	11.38	8.83	10.97	12.50	8.08	7.18
range	185.4 to 267.0	119.7 to 168.4	98.2 to 132.6	72.2 to 118.0	61.1 to 110.6	48.5 to 85.4	44.4 to 76.0

PRESOAK

chain #	initial	1h	1d	1w	2w	3w	4w
1	187.3	126.1	108.9	74.7	65.7	62.1	49.4
2	195.0	124.2	107.8	67.4	65.3	63.8	48.4
3	199.8	125.1	112.5	69.3	67.4	65.3	44.9
4	1[illegible]6.2	116.7	112.8	62.8	60.1	56.6	44.2
5	187.2	121.9	83.7	69.7	59.0	57.6	37.8
6	195.5	128.0	95.6	59.5	58.5	55.1	44.5
7	203.8	128.0	100.8	77.5	76.8	66.9	53.5
8	197.0	123.2	96.2	61.9	60.4	49.1	38.3
9	176.6	117.2	89.1	68.1	66.7	57.9	46.1
10	191.1	136.2	102.8	73.0	72.4	59.5	50.0
11	183.3	124.8	101.0	69.7	68.1	62.1	47.8
12	207.7	134.5	103.4	75.4	68.6	56.8	44.7
13	191.9	134.2	101.7	73.1	66.8	60.4	48.5
14	180.4	129.2	99.7	71.5	68.9	65.5	50.9
15	200.8	135.9	112.0	76.5	65.6	57.2	41.6
16	197.3	135.0	110.5	71.2	68.8	67.5	49.9
17	176.5	124.9	87.5	66.3	65.5	61.8	44.8
18	193.2	125.0	94.4	71.0	70.8	66.7	47.2
19	179.5	133.3	94.6	67.3	56.9	53.3	43.7
20	166.4	117.5	90.5	63.3	60.2	46.7	33.1
21	190.3	126.0	95.4	74.6	72.0	64.7	48.3
22	178.6	113.5	91.9	66.6	65.3	55.9	44.8
23	175.2	120.7	87.6	65.8	62.1	50.0	42.2
24	206.2	139.9	99.1	68.5	65.9	57.9	46.0
25	181.1	125.6	89.7	57.2	56.7	48.7	37.2
26	179.3	114.1	92.5	71.1	68.0	54.[illegible]	41.0
27	195.8	125.7	94.6	73.1	70.0	60.2	49.1
28	174.9	113.1	89.2	67.6	61.4	52.3	35.2
29	184.5	116.9	89.8	69.5	67.3	52.0	36.9
mean	188.36	125.39	97.77	69.08	65.56	58.22	44.48
std dev	10.35	7.24	8.25	4.86	4.83	5.78	5.03
range	166.4 to 207.7	113.1 to 139.9	83.7 to 112.8	57.2 to 77.5	56.7 to 76.8	46.7 to 67.5	33.1 to 53.5

comment- chain # 8 slipped off pin/bracket assembly
Data for this chain not entered
thus n=29 for this group

40PRESOAK

chain #	initial	1h	1d	1w	2w	3w	4w
1	173.0	114.1	99.8	67.6	66.2	46.0	40.1
2	188.9	121.4	100.0	72.9	68.3	56.4	49.4
3	162.2	114.8	86.9	67.1	60.2	46.9	45.4
4	188.0	127.3	102.6	74.6	67.1	51.2	46.4
5	167.5	116.5	98.3	69.0	66.2	46.8	45.9
6	198.0	133.7	104.3	76.6	72.2	56.7	52.5
7	183.4	121.7	88.8	64.8	62.2	45.6	39.2
8	187.3	133.2	109.7	93.5	80.1	65.8	58.2
9	168.5	113.1	95.9	63.9	59.7	42.2	39.8
10	169.6	116.8	103.5	61.0	57.7	51.2	44.1
11	206.9	139.8	116.3	90.1	84.4	69.5	58.6
12	190.0	139.4	112.8	80.0	75.3	56.7	50.4
13	170.8	127.5	108.1	72.0	66.2	49.9	47.7
14	179.9	133.2	104.5	73.2	62.9	44.5	40.5
15	182.5	135.9	114.6	77.6	71.1	61.7	43.1
16	178.9	121.4	101.6	60.4	57.7	53.8	49.2
17	167.9	102.9	85.8	57.2	55.6	42.6	38.8
18	182.4	120.7	99.9	74.5	68.4	57.7	53.5
19	171.3	111.9	94.9	63.5	60.6	48.1	41.8
20	169.4	116.9	97.2	66.9	62.2	55.0	47.3
21	195.8	133.5	111.9	76.9	73.3	63.6	58.7
22	187.9	137.8	104.4	81.3	77.2	67.0	65.0
23	196.5	137.0	118.4	80.8	75.9	61.5	57.7
24	178.3	129.3	107.5	72.2	69.3	54.2	50.3
25	179.9	131.8	116.5	78.2	77.8	57.5	51.5
26	193.0	135.6	105.8	63.9	60.1	46.5	41.1
27	191.1	132.3	105.0	73.9	67.4	56.1	49.7
28	191.5	126.0	111.5	72.3	68.1	57.2	51.3
29	180.7	130.7	105.5	78.2	75.0	59.3	55.6
mean	182.1	126.1	103.9	72.6	67.9	54.2	48.7
std dev	10.88	9.58	8.37	8.28	7.27	7.35	6.79
range	162.2 to 206.9	102.9 to 139.8	85.8 to 118.4	57.2 to 93.5	55.6 to 84.4	42.2 to 69.5	38.8 to 65.0

CONTROL2

chain#	initial	1h	1d	1w	2w	3w	4w
1	248.6	148.4	109.1	81.3	73.2	60.1	45.5
2	249.6	145.5	111.1	85.3	78.7	62.0	46.4
3	215.9	132.7	104.6	78.3	70.7	58.6	34.1
4	249.5	143.2	112.3	90.3	78.6	66.7	46.8
5	255.0	154.3	119.0	91.5	89.3	73.3	66.3
6	222.8	133.5	105.1	80.7	70.8	62.3	62.3
7	244.3	145.7	113.0	90.7	85.7	75.6	60.2
8	246.9	127.3	105.7	77.1	65.1	46.9	40.9
9	226.0	124.5	94.9	78.6	63.0	44.0	27.2
10	241.4	134.4	107.5	84.0	73.4	60.6	47.9
11	250.2	149.4	121.8	92.2	88.0	80.1	75.5
12	234.1	145.9	118.7	85.8	73.8	70.4	66.3
13	234.4	154.4	121.9	84.4	86.0	67.0	59.2
14	225.9	130.1	117.0	85.5	79.3	73.9	53.5
15	228.3	132.9	116.0	83.4	76.8	72.2	56.9
16	235.9	147.5	119.2	88.9	79.5	73.1	55.4
17	223.0	149.8	121.2	94.0	82.0	71.2	65.5
18	248.0	154.7	125.3	95.8	89.5	70.8	54.6
19	243.2	163.5	128.0	95.0	84.8	76.7	51.8
20	227.4	150.3	117.6	84.2	78.2	67.9	52.3
21	246.2	148.9	112.3	87.6	71.1	58.0	39.9
22	235.7	164.2	119.0	88.7	81.0	65.1	56.3
23	221.9	143.8	114.0	86.6	77.5	69.8	52.5
24	209.7	138.4	105.7	73.0	69.7	64.1	50.1
25	209.1	138.4	105.7	88.6	71.4	61.0	48.2
26	219.8	137.3	106.2	83.2	61.7	61.0	43.1
27	214.3	139.1	106.9	80.9	64.9	59.0	36.7
28	220.7	151.6	109.8	85.7	70.7	67.5	58.0
29	223.4	155.2	114.0	89.7	80.7	62.7	58.5
30	221.9	155.2	111.6	81.0	73.7	57.7	52.2
mean	232.4	144.7	113.1	85.7	76.3	65.3	52.1
std dev	13.2	10.03	7.20	5.40	7.55	8.02	10.27
range	209.1 to 255.0	124.5 to 164.2	94.9 to 128.0	73.0 to 95.8	61.7 to 89.5	44.0 to 80.1	27.2 to 75.5

CHEM4

chain#	initial	1h	1d	1w	2w	3w	4w
1	218.0	156.2	124.4	102.3	85.9	70.7	65.4
2	210.6	148.6	132.7	100.6	74.8	59.9	43.2
3	215.0	148.2	125.7	100.8	80.1	69.7	63.1
4	190.5	136.1	119.7	90.2	63.9	53.0	49.1
5	187.7	132.2	103.9	83.1	57.4	49.4	31.4
6	187.2	128.2	105.0	79.5	66.7	56.4	49.1
7	217.2	152.3	135.1	107.0	92.4	75.1	54.1
8	202.9	141.6	125.6	100.4	76.8	69.8	54.3
9	208.0	154.6	122.9	96.3	74.0	60.5	36.5
10	226.9	154.1	126.8	102.1	78.2	73.0	69.4
11	208.5	144.4	126.8	98.1	78.7	62.8	53.4
12	216.0	157.7	134.0	106.9	95.1	79.2	60.5
13	233.1	164.1	138.3	105.1	87.1	73.8	70.3
14	232.2	169.2	139.9	111.8	88.7	86.0	69.1
15	210.5	151.0	132.2	105.9	82.3	77.3	45.1
16	179.3	130.7	111.5	81.8	60.8	57.2	44.6
17	232.2	167.2	138.1	110.2	89.2	64.4	50.2
18	207.2	146.0	130.2	96.6	75.4	64.6	52.1
19	195.7	146.5	122.9	101.0	63.6	60.9	37.6
20	206.4	135.9	111.1	92.8	80.8	72.4	48.4
21	213.1	150.7	126.7	107.8	83.9	63.0	46.4
22	201.4	148.9	120.6	94.1	80.1	66.6	47.3
23	238.2	159.2	127.9	109.6	85.0	73.0	52.3
24	200.7	141.6	125.7	107.3	84.0	81.4	57.0
25	202.8	148.1	125.0	99.7	70.2	68.6	56.3
26	239.6	160.3	129.6	112.2	78.9	63.5	50.3
27	224.2	161.2	133.3	110.6	78.7	69.3	60.3
28	228.8	157.1	131.1	110.6	87.5	85.0	61.4
29	240.0	167.9	142.4	120.1	88.6	75.4	54.9
30	232.0	165.7	139.0	115.2	79.5	77.1	45.7
mean	213.5	150.9	126.9	102.0	78.9	68.6	52.6
std dev	16.39	11.08	9.49	9.59	9.25	8.93	9.48
range	179.3 to 240.0	128.2 to 169.2	103.9 to 142.4	79.5 to 120.1	57.4 to 95.1	49.4 to 86.0	31.4 to 70.3

EO1

chain#	initial	1h	1d	1w	2w	3w	4w
1	259.1	177.6	146.3	117.1	94.0	84.8	66.0
2	265.1	174.4	130.7	98.1	83.1	82.3	55.4
3	250.0	170.7	141.5	121.8	106.0	48.7	67.8
4	260.0	190.8	146.5	127.2	109.4	93.7	86.6
5	264.9	174.7	133.7	116.5	95.8	86.4	70.5
6	258.1	169.8	132.8	110.9	90.9	80.9	67.3
7	255.2	178.9	140.6	122.4	100.1	91.7	64.2
8	250.2	175.5	138.3	116.2	94.4	86.2	70.8
9	253.8	175.1	135.5	112.3	91.7	88.8	70.5
10	254.1	178.5	132.5	119.8	93.4	83.9	70.0
11	234.[illegible]	[illegible]	[illegible]	121.8	105.3	76.2	70.4
12	228.[illegible]	[illegible]	[illegible]	116.2	87.7	87.8	61.7
13	248.4	179.4	[illegible]	115.8	92.8	80.0	63.6
14	268.9	191.8	152.6	125.7	108.7	100.0	77.8
15	257.0	192.2	152.9	127.2	108.7	102.0	80.8
16	251.2	185.3	148.1	113.4	94.2	87.0	81.2
17	244.2	182.4	151.3	125.6	100.8	96.2	82.7
18	265.2	186.6	154.4	122.6	104.5	95.7	74.6
19	261.3	189.9	146.9	122.3	109.3	96.9	73.9
20	262.2	186.1	148.1	120.3	102.8	94.0	68.8
21	246.4	174.4	137.5	114.5	100.8	83.1	67.3
22	261.7	178.7	154.4	121.4	97.6	78.6	73.3
23	238.8	170.2	141.1	120.8	92.3	84.5	66.2
24	275.1	189.0	156.0	126.0	104.4	94.6	82.5
25	251.6	173.1	142.5	109.9	94.3	81.1	70.1
26	276.0	198.6	159.1	134.6	113.5	102.4	86.8
27	242.8	181.9	145.4	113.7	96.2	85.7	76.7
28	244.4	179.7	151.4	118.1	99.3	81.2	63.8
29	243.1	176.6	142.1	121.5	100.0	89.1	71.6
30	239.5	173.7	139.5	114.8	94.2	91.4	69.6
mean	253.7	180.2	144.0	119.0	98.9	87.2	71.8
st. dev.	11.31	7.61	7.65	6.70	7.15	9.93	7.37
range	228.4 to 276.0	167.7 to 198.6	130.7 to 159.1	98.1 to 134.6	83.1 to 113.5	48.7 to 102.4	55.4 to 86.8

EO4

chain#	initial	1h	1d	1w	2w	3w	4w
1	254.3	180.6	149.7	124.0	100.1	95.5	78.6
2	231.6	160.7	135.2	111.9	102.0	89.7	57.4
3	270.6	187.1	158.6	133.3	100.0	81.2	60.4
4	262.2	174.0	147.9	125.7	95.4	87.5	74.5
5	253.2	175.8	143.5	125.5	100.9	86.0	70.1
6	265.7	177.0	149.1	114.4	89.5	80.6	76.2
7	239.3	162.1	136.4	115.5	93.6	85.5	68.5
8	260.8	184.0	154.5	131.3	112.7	104.6	77.8
9	257.5	173.2	149.6	116.0	98.8	90.3	70.8
10	283.8	181.8	155.8	130.2	111.6	104.0	76.5
11	285.9	182.5	147.2	123.4	107.8	92.6	73.2
12	256.1	164.6	134.7	118.9	90.6	87.3	62.9
13	255.7	175.2	142.1	120.3	98.7	86.2	61.8
14	255.8	169.7	138.6	121.3	99.4	80.9	68.7
15	259.0	173.8	139.0	120.5	104.8	90.1	79.9
16	249.4	174.2	134.0	112.1	97.1	83.1	66.0
17	250.5	165.2	142.4	120.8	90.7	88.0	69.6
18	250.6	174.9	142.5	112.8	100.3	90.1	85.8
19	262.9	171.5	136.0	110.0	94.2	78.8	66.0
20	246.2	169.6	134.8	108.2	97.2	83.7	80.7
21	254.3	172.5	144.5	117.4	98.5	91.0	64.9
22	252.2	174.0	145.0	121.9	105.1	85.1	66.9
23	260.4	171.9	146.7	120.4	96.6	84.8	70.0
24	263.6	183.5	157.6	123.0	104.5	91.7	80.9
25	245.4	175.2	149.6	128.2	105.4	94.9	69.9
26	235.3	168.6	138.8	111.6	87.6	81.1	63.2
27	243.5	182.0	153.3	128.0	105.7	99.7	79.5
28	244.3	170.2	143.2	118.3	98.8	87.6	68.3
29	235.5	171.3	138.0	119.5	97.9	84.3	69.4
30	266.0	182.8	151.0	128.1	102.1	94.7	75.5
mean	255.1	174.3	144.6	120.4	99.6	88.7	71.1
st. dev.	12.38	6.53	7.12	6.52	5.96	6.42	6.83
range	231.6 to 285.9	160.7 to 187.1	134.0 to 158.6	108.2 to 133.3	87.6 to 112.7	78.8 to 104.6	57.4 to 85.8

Control % initial force remaining

chain#	%1h	%1d	%1w	%2w	%3w	%4w
	58.60	47.60	31.60	28.37	22.54	20.02
	56.36	52.83	36.75	27.07	22.14	18.44
3	60.98	49.23	33.31	28.75	22.84	20.89
4	59.38	46.58	27.58	26.38	24.63	18.38
5	67.57	54.67	37.17	32.16	25.36	23.69
6	64.59	47.84	32.21	29.91	22.42	18.23
7	62.83	47.99	32.81	29.47	22.80	19.[illegible]
8	60.01	44.16	31.00	29.06	22.06	[illegible]
9	61.08	46.79	31.80	30.63	20.81	1[illegible].6[illegible]
10	64.42	51.69	32.93	32.66	21.28	19.[illegible]
11	67.02	51.93	33.23	31.52	24.19	21.61
12	68.73	55.00	29.67	28.61	24.09	20.59
13	64.30	52.68	32.45	31.43	26.19	24.17
14	65.26	53.09	35.44	34.45	24.58	23.47
15	67.60	51.63	35.75	3[illegible].74	26.20	25.27
16	65.67	52.06	34.58	30.[illegible]	27.77	24.62
17	65.73	58.25	34.14	31.11	28.48	25.84
18	70.62	61.62	39.18	34.30	28.97	25.21
19	63.53	45.96	32.89	29.26	22.96	17.91
20	65.45	47.17	30.26	28.65	26.16	20.13
21	62.64	43.13	28.68	28.55	27.11	20.85
22	63.15	48.48	28.41	27.71	23.02	20.02
23	63.83	49.11	34.06	30.68	24.83	20.99
24	60.09	43.89	27.40	25.57	22.26	16.33
25	63.10	43.94	29.45	27.94	23.55	20.58
26	65.32	48.53	32.08	29.57	25.71	19.54
27	74.32	54.34	34.70	33.19	28.61	22.08
28	68.85	53.18	31.90	28.51	25.82	20.82
mean	64.3	50.1	32.6	30.0	24.6	20.7
std dev	3.79	4.39	2.85	2.23	2.34	2.70
range	56.4 to 74.3	43.1 to 61.6	27.4 to 39.2	25.6 to 34.5	20.8 to 29.0	15.9 to 25.8

CHEM1 % INITIAL FORCE

chain#	% 1	%1d	%1w	%2w	%3w	%4w
1	67.67	58.69	52.46	45.64	33.17	25.36
2	64.58	56.04	47.59	41.84	34.49	32.12
3	61.67	55.48	50.00	45.02	28.07	26.61
4	64.75	52.00	48.50	44.06	31.31	24.50
5	64.50	49.33	41.89	40.59	24.83	23.53
6	58.67	47.70	42.91	37.52	25.76	23.83
7	68.39	56.92	51.23	48.72	29.44	26.72
8	64.62	54.30	49.29	46.20	35.67	29.24
9	63.07	49.63	40.45	39.21	26.55	21.61
10	62.29	53.21	43.08	39.96	28.58	25.00
11	60.65	49.14	41.40	37.13	25.62	22.94
12	62.93	51.05	40.63	34.36	22.35	21.49
13	62.81	50.82	43.41	40.62	26.67	24.34
14	65.63	61.10	43.38	42.49	34.05	31.89
15	65.02	55.62	43.15	39.02	28.13	27.83
16	63.26	55.92	40.18	39.36	28.67	27.66
17	65.75	56.14	42.11	40.64	28.74	27.77
18	65.78	50.31	43.14	39.14	30.17	24.64
19	64.46	53.20	39.69	38.54	26.63	24.77
20	63.37	57.51	42.77	37.55	33.06	31.50
21	67.41	57.21	43.20	30.66	28.11	26.28
22	73.88	59.29	48.48	38.03	33.12	31.26
23	64.73	59.68	45.94	30.39	29.65	27.89
24	71.08	57.41	48.39	34.44	31.41	29.30
25	65.61	54.69	43.05	32.93	22.85	20.91
26	63.87	56.03	45.78	44.29	26.89	25.24
27	66.47	58.04	39.58	32.75	28.54	26.79
28	70.82	59.06	38.94	35.33	31.45	29.88
29	68.85	55.32	38.51	31.24	30.25	26.92
30	66.90	54.31	34.55	28.60	28.23	25.66
mean	65.32	54.84	43.79	38.54	29.08	26.45
std dev	3.12	3.47	4.12	5.02	3.26	3.01
range	58.67 to 73.88	47.70 to 61.10	34.55 to 52.46	28.60 to 48.72	22.35 to 35.67	20.91 to 32.12

PRESOAK % INITIAL FORCE

chain#	%1h	%1d	%1w	%2w	%3w	%4w
1	67.33	58.14	39.88	35.08	33.16	26.37
2	63.69	55.28	34.56	33.49	32.72	24.82
3	62.61	56.31	34.68	33.73	32.68	22.47
4	62.67	60.58	33.73	32.28	30.40	23.74
5	65.12	44.71	37.23	31.52	30.77	20.19
6	65.47	48.90	30.43	29.92	28.18	22.76
7	62.81	49.46	38.03	37.68	32.83	26.25
8	62.54	48.83	31.42	30.66	24.92	19.44
9	66.36	50.45	38.56	37.77	32.79	26.10
10	71.27	53.79	38.20	37.89	31.14	26.16
11	68.09	55.10	38.03	37.15	33.88	26.08
12	64.76	49.78	36.30	33.03	27.35	21.52
13	69.93	53.00	38.09	34.81	31.47	25.27
14	71.62	55.27	39.63	38.19	36.31	28.22
15	67.68	55.78	38.10	32.67	28.49	20.[illegible]
16	68.42	56.01	36.09	34.87	34.21	25.29
17	70.76	49.58	37.56	37.11	35.01	25.38
18	64.70	48.86	36.75	36.65	34.52	24.43
19	74.26	52.70	37.49	31.70	29.69	24.35
20	70.61	54.39	38.04	36.18	28.06	19.89
21	66.21	50.13	39.20	37.83	34.00	25.38
22	63.55	51.46	37.29	36.56	31.30	25.08
23	68.89	50.00	37.56	35.45	28.54	24.09
24	67.85	48.06	33.22	31.96	28.08	22.31
25	69.35	49.53	31.58	31.31	26.89	20.54
26	63.64	51.59	39.65	37.93	30.56	22.87
27	64.20	48.31	37.33	35.75	30.75	25.08
28	64.67	51.00	38.65	35.11	29.90	20.13
29	63.36	48.67	37.67	36.48	28.18	20.00
mean	66.64	51.93	36.72	34.86	30.92	23.62
std dev	3.17	3.52	2.49	2.49	2.74	2.41
range	62.5 to 74.3	44.7 to 60.6	30.4 to 39.9	29.9 to 38.2	24.9 to 36.3	19.4 to 28.2

40PRESOAK % INITIAL FORCE

chain#	%1h	%1d	%1w	%2w	%3w	%4w
1	65.95	57.69	39.08	38.27	26.59	23.18
2	64.27	52.94	38.59	36.16	29.86	26.15
3	70.78	53.58	41.37	37.11	28.91	27.99
4	67.71	54.57	39.68	35.69	27.23	24.68
5	69.55	58.69	41.19	39.52	27.94	27.40
6	67.53	52.68	38.69	36.46	28.64	26.52
7	66.36	48.42	35.33	33.91	24.86	21.37
8	71.12	58.57	49.92	42.77	35.13	31.07
9	67.12	56.91	37.92	35.43	25.04	23.62
10	68.87	61.03	35.97	34.02	30.19	26.00
11	67.57	56.21	43.55	40.79	33.59	28.32
12	73.37	59.37	42.11	39.63	29.84	26.53
13	74.65	63.29	42.15	38.76	29.22	27.93
14	74.04	58.09	40.69	34.96	24.74	22.51
15	74.47	62.79	42.52	38.96	33.81	23.62
16	67.86	56.79	33.76	32.25	30.07	27.50
17	61.29	51.10	34.07	33.11	25.37	23.11
18	66.17	54.77	40.84	37.50	31.63	29.33
19	65.32	55.40	37.07	35.38	28.08	24.40
20	69.01	57.38	39.49	36.72	32.47	27.92
21	68.18	57.15	39.27	37.44	32.48	29.98
22	73.34	55.56	43.27	41.09	35.66	34.59
23	69.72	60.25	41.12	38.63	31.30	29.36
24	72.52	60.29	40.49	38.87	30.40	28.21
25	73.26	64.76	43.47	43.25	31.96	28.63
26	70.26	54.82	33.11	31.14	24.09	21.30
27	69.23	54.95	38.67	35.27	29.36	26.01
28	65.80	58.22	37.75	35.56	29.87	26.79
29	72.33	58.38	43.28	41.51	32.82	30.77
mean	69.2	57.1	39.8	37.2	29.7	26.7
std dev	3.30	3.56	3.47	2.98	3.10	3.04
	61.3 to 74.7	48.4 to 64.8	33.1 to 49.9	31.14 to 43.25	24.1 to 35.7	21.3 to 34.6

CONTROL2 % INITIAL FORCE

chain#	1h	1d	1w	2w	3w	4w
1	59.7	43.89	32.70	29.44	24.18	18.30
2	58.3	44.51	34.17	31.53	24.84	18.59
3	61.5	48.45	36.27	32.75	27.14	15.79
4	57.4	45.01	36.19	31.50	26.73	18.76
5	60.5	46.67	35.88	35.02	28.75	26.00
6	59.9	47.17	36.22	31.78	27.96	27.96
7	59.6	46.25	37.13	35.08	30.95	24.64
8	51.6	42.81	31.23	26.37	19.00	16.57
9	55.1	41.99	34.78	27.88	19.47	12.04
10	55.7	44.53	34.80	30.41	25.10	19.84
11	59.7	48.68	36.85	35.17	32.01	30.18
12	62.3	50.70	36.65	31.52	30.07	28.32
13	65.9	52.01	36.01	36.69	28.58	25.26
14	57.6	51.79	37.85	35.10	32.71	23.68
15	58.2	50.81	36.53	33.64	31.63	24.92
16	62.5	50.53	37.69	33.70	30.99	23.48
17	67.2	54.35	42.15	36.77	31.93	29.37
18	62.4	50.52	38.63	36.09	28.55	22.02
19	67.2	52.63	39.06	34.87	31.54	21.30
20	66.1	51.72	37.03	34.39	29.86	23.00
21	60.5	45.61	35.58	28.88	23.56	16.21
22	69.7	50.49	37.63	34.37	27.62	23.89
23	64.8	51.37	39.03	34.93	31.46	23.66
24	66.0	50.41	34.81	33.24	30.57	23.89
25	66.2	50.55	42.37	34.15	29.17	23.05
26	62.5	48.32	37.85	28.07	27.75	19.61
27	64.9	49.88	37.75	30.28	27.53	17.13
28	68.7	49.75	38.83	32.03	30.58	26.28
29	69.5	51.03	40.15	36.12	28.07	26.19
30	69.9	50.29	36.50	33.21	26.00	23.52
mean	62.4	48.8	36.9	32.8	28.1	22.4
std dev	4.64	3.12	2.33	2.74	3.39	4.32
range	51.6 to 69.9	42.0 to 54.4	31.2 to 42.4	26.4 to 36.8	19.0 to 32.7	12.0 to 30.2

CHEM4 % INITIAL FORCE

chain#	1h	1d	1w	2w	3w	4w
1	71.65	57.06	46.93	39.40	32.43	30.00
2	70.56	63.01	47.77	35.52	28.44	20.51
3	68.93	58.47	46.88	37.26	32.42	29.35
4	71.44	62.83	47.35	33.54	27.82	25.77
5	70.43	55.35	44.27	30.58	26.32	16.73
6	68.48	56.09	42.47	35.63	30.13	26.23
7	70.12	62.20	49.26	42.54	34.58	24.91
8	69.79	61.90	49.48	37.85	34.40	26.76
9	74.33	59.09	46.30	35.58	29.09	17.55
10	67.92	55.88	45.00	34.46	32.17	30.59
11	69.26	60.82	47.05	37.75	30.12	25.61
12	73.01	62.04	49.49	44.03	36.67	28.01
13	70.40	59.33	45.09	37.37	31.66	30.16
14	72.87	60.25	48.15	38.20	37.04	29.76
15	71.73	62.80	50.31	39.10	36.72	21.43
16	72.89	62.19	45.62	33.91	31.90	24.87
17	72.01	59.47	47.46	38.42	27.73	21.62
18	70.46	62.84	46.62	36.39	31.18	25.14
19	74.86	62.80	51.61	32.50	31.12	19.21
20	65.84	53.83	44.96	39.15	35.08	23.45
21	70.72	59.46	50.59	39.37	29.56	21.77
22	73.93	59.88	46.72	39.77	33.07	23.49
23	66.83	53.69	46.01	35.68	30.65	21.96
24	70.55	62.63	53.46	41.85	40.56	28.40
25	73.03	61.64	49.16	34.62	33.83	27.76
26	66.90	54.09	46.83	32.93	26.50	20.99
27	71.90	59.46	49.33	35.10	30.91	26.90
28	68.66	57.30	48.34	38.24	37.15	26.84
29	69.96	59.33	50.04	36.92	31.42	22.88
30	71.42	59.91	49.66	34.27	33.23	19.70
mean	70.70	59.52	47.74	36.93	32.13	24.61
std dev	2.19	2.88	2.32	2.99	3.34	3.81
range	65.84 to 74.86	53.69 to 63.01	42.47 to 53.46	30.58 to 44.03	26.32 to 40.56	16.73 to 30.59

EO1 % INITIAL FORCE

chain#	1h	1d	1w	2w	3w	4w
1	68.54	56.46	45.19	36.28	32.73	25.47
2	65.79	49.30	37.00	31.35	31.04	20.90
3	68.28	56.60	48.72	42.40	19.48	27.12
4	73.38	56.35	48.92	42.08	36.04	33.31
5	65.95	50.47	43.98	36.16	32.62	26.61
6	65.79	51.45	42.97	35.22	31.34	26.08
7	70.10	55.09	47.96	39.22	35.93	25.16
8	70.14	55.28	46.44	37.73	34.45	28.30
9	68.99	53.39	44.25	36.13	34.99	27.78
10	70.25	52.14	47.15	36.76	33.02	27.55
11	77.98	50.26	51.98	44.94	32.52	30.05
12	73.42	58.63	50.88	38.40	38.44	27.01
13	72.22	57.81	46.62	37.36	32.21	25.60
14	71.33	56.75	46.75	40.42	37.19	28.93
15	74.79	59.49	49.49	42.30	39.69	31.44
16	73.77	58.96	45.14	37.50	34.63	32.32
17	74.69	61.96	51.43	41.28	39.39	33.87
18	70.36	58.22	46.23	39.40	36.09	28.13
19	72.68	56.22	46.80	41.83	37.08	28.28
20	70.98	56.48	45.88	39.21	35.85	26.24
21	70.78	55.80	46.47	40.91	33.73	27.31
22	68.28	59.00	46.39	37.29	30.03	28.01
23	71.27	59.09	50.59	38.65	35.39	27.72
24	68.70	56.71	45.80	37.95	34.39	29.99
25	68.80	56.64	43.68	37.48	32.23	27.86
26	71.96	57.64	48.77	41.12	37.10	31.45
27	74.92	59.88	46.83	39.62	35.30	31.59
28	73.53	61.95	48.32	40.63	33.22	26.10
29	72.65	58.45	49.98	41.14	36.65	29.45
30	72.53	58.25	47.93	39.33	38.16	29.06
mean	71.10	56.82	46.95	39.00	34.36	28.29
std dev	2.86	3.02	2.92	2.67	3.69	2.67
range	65.79 to 77.98	49.30 to 61.96	37.00 to 51.98	31.35 to 44.94	19.48 to 39.69	20.90 to 33.87

EO4 % INITIAL FORCE

chain#	1h	1d	1w	2w	3w	4w
1	71.02	58.87	48.76	39.36	37.55	30.91
2	69.39	58.38	48.32	44.04	38.73	24.78
3	69.14	58.61	49.26	36.95	30.01	22.32
4	66.36	56.41	47.94	36.38	33.37	28.41
5	69.43	56.67	49.57	39.85	33.97	27.69
6	66.62	56.12	43.06	33.68	30.33	28.68
7	67.74	57.00	48.27	39.11	35.73	28.63
8	70.55	59.24	50.35	43.21	40.11	29.83
9	67.26	58.10	45.05	38.37	35.07	27.50
10	64.06	54.90	45.88	39.32	36.65	26.96
11	63.83	51.49	43.16	37.71	32.39	25.60
12	64.27	52.60	46.43	35.38	34.09	24.56
13	68.52	55.57	47.05	38.60	33.71	24.17
14	66.34	54.18	47.42	38.86	31.63	26.86
15	67.10	53.67	46.53	40.46	34.79	30.85
16	69.85	53.73	44.95	38.93	33.32	26.46
17	65.95	56.85	48.22	36.21	35.13	27.78
18	69.79	56.86	45.01	40.02	35.95	34.24
19	65.23	51.73	41.84	35.83	29.97	25.10
20	68.89	54.75	43.95	39.48	34.00	32.78
21	67.83	56.82	46.17	38.73	35.78	25.52
22	68.99	57.49	48.33	41.67	33.74	26.53
23	66.01	56.34	46.24	37.10	32.57	26.88
24	69.61	59.79	46.66	39.64	34.79	30.69
25	71.39	60.96	52.24	42.95	38.67	28.48
26	71.65	58.99	47.43	37.23	34.47	26.86
27	74.74	62.96	52.57	43.41	40.94	32.65
28	69.67	58.62	48.42	40.44	35.86	27.96
29	72.74	58.60	50.74	41.57	35.80	29.47
30	68.72	56.77	48.16	38.38	35.60	28.38
mean	68.42	56.77	47.26	39.10	34.83	27.92
standar deviation	2.54	2.60	2.51	2.44	2.64	2.66
range	63.80 to 74.70	51.50 to 63.00	41.80 to 52.60	33.70 to 44.00	30.00 to 40.90	22.30 to 34.20

APPENDIX 4

Force/Extension
Chains stretched 6-5-3
3 loop chain
force (gms)

group	A	B	C	D	E
	102.4	171.0	293.0	346.7	370.6
	129.0	192.4	305.2	344.9	388.5
	105.7	204.4	297.9	338.5	393.9
	130.1	216.7	291.9	362.5	382.9
	122.2	205.2	305.9	344.7	403.1
	117.4	204.1	284.1	373.8	413.3
	138.9	211.1	292.0	371.0	393.7
	122.7	198.7	273.9	368.2	381.[illegible]
	107.7	196.5	284.0	345.6	398.[illegible]
	121.3	207.3	297.4	359.3	395.2
mean	119.7	200.7	292.5	355.5	392.2
st.dev	11.1	11.9	9.4	12.2	11.4

Force/Extension
Chains stretched 6-5-3
4 loop chain
force (gms)

group	F	G	H	I
	67.4	106.8	166.5	206.1
	65.0	112.1	169.1	187.5
	55.9	107.0	166.0	219.9
	50.6	118.3	170.3	204.8
	43.4	131.4	152.1	200.7
	50.6	112.6	164.7	212.0
	53.5	126.1	157.1	203.2
	52.1	126.9	140.7	186.7
	53.0	109.9	163.3	197.6
	57.1	127.4	177.6	183.0
mean	54.8	117.9	162.7	200.2
st.dev	6.7	8.9	9.9	11.1

group	J	K	L	M	N
	260.5	249.7	296.4	327.6	381.0
	233.4	241.8	287.7	324.3	366.0
	239.4	274.6	283.7	350.8	365.5
	250.3	264.7	300.8	362.5	364.2
	238.7	272.2	300.1	356.5	376.2
	237.1	275.2	301.9	361.3	376.7
	238.2	272.9	263.8	336.8	381.3
	243.0	265.9	307.9	339.0	363.5
	247.2	276.4	300.2	348.2	367.9
	244.5	278.2	309.2	366.4	368.5
mean	243.2	267.2	295.2	347.3	371.1
st.dev	7.5	11.6	12.9	14.1	6.6

APPENDIX 5

SUMMARY TABLE OF F-RATIOS

	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
Group	385005.31	81108.67	55000.76	375.50	146.47	7.0	216.0	0.0
Time	0.44542E7	48098.33	742367.41	37.11	20002.94			
Greenhouse-Geiser Adj.	EPSILON	0.59				3.5	760.2	0.0
GroupTime	69237.05	48098.33	1648.50	37.11	44.42			
Greenhouse-Geiser Adj.	EPSILON	0.59				24.6	760.2	0.0

ANALYSIS OF VARIANCE
TIME - INITIAL
P<0.0000446

GROUP				40PS	PS	CHEM4	CHEM1	CTRL	CTRL2	EO1	EO8
40PS	FREQ.	(28.0)									
	ESTMEAN	182.16									
PS	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	188.50	OBS DIFF	6.34							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	211.92	OBS DIFF	29.77	23.43						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	217.12	OBS DIFF	34.96	28.62	5.19					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	4.10	4.10	4.10					
CTRL	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	226.69	OBS DIFF	44.54	38.20	14.77	9.57				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	233.14	OBS DIFF	50.98	44.64	21.21	16.02	6.44			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
EO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67		
	ESTMEAN	254.59	OBS DIFF	72.43	66.09	42.66	37.47	27.89	21.45		
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63		
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00		
			LSD	4.10	4.10	4.10	4.10	4.10	4.10		
EO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17	10.17	
	ESTMEAN	255.36	OBS DIFF	73.20	66.86	43.44	38.24	28.67	22.22	0.77	
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47	2.47	
			D.F	517.79	517.79	517.79	517.79	517.79	517.79	517.79	
			LSD	4.12	4.12	4.12	4.12	4.12	4.12	4.12	

ANALYSIS OF VARIANCE
TIME - 1 HOUR
P<0.0000446

GROUP				PS	40PS	CHEM1	CTRL2	CTRL	CHEM4	EO8	EO1
PS	FREQ.	(28.0)									
	ESTMEAN	125.70									
40PS	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	125.91	OBS DIFF	0.21							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	5.67						
	ESTMEAN	141.18	OBS DIFF	15.48	15.27						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	143.18	OBS DIFF	18.22	18.01	2.74					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	41.10	4.10	4.10					
CTRL	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	145.67	OBS DIFF	19.98	19.76	4.50	1.76				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	149.71	OBS DIFF	24.01	23.80	8.53	5.79	4.04			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
EO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17		
	ESTMEAN	174.12	OBS DIFF	48.42	48.21	32.94	30.20	28.45	24.41		
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47		
			D.F	517.79	517.79	517.79	517.79	517.79	517.79		
			LSD	4.12	4.12	4.12	4.12	4.12	4.12		
EO1	FREQ.	(28.0)	REQ [illegible]IFF	6.67	6.67	6.67	6.67	6.67	6.67	10.17	
	ESTMEAN	180.56	OBS [illegible]FF	54.86	54.65	39.38	36.64	34.89	30.85	6.44	
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63	2.47	
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00	517.79	
			LSD	4.10	4.10	4.10	4.10	4.10	4.10	4.12	

ANALYSIS OF VARIANCE
TIME - 1 DAY
P<0.0000446

GROUP				PS	40PS	CTRL2	CTRL	CHEM1	CHEM4	BO1	BO8
PS	FREQ.	(28.0)									
	ESTMEAN	98.05									
40PS	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	103.80	OBS DIFF	5.75							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	113.16	OBS DIFF	15.11	9.36						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CTRL	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	113.64	OBS DIFF	15.59	9.84	0.47					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	41.10	4.10	4.10					
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	118.69	OBS DIFF	20.63	14.88	5.52	5.05				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	125.95	OBS DIFF	27.90	22.15	12.79	12.31	7.27			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
BO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67		
	ESTMEAN	144.24	OBS DIFF	46.19	40.44	31.08	30.60	25.56	18.29		
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63		
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00		
			LSD	4.10	4.10	4.10	4.10	4.10	4.10		
BO8	FREQ.	(28.0)	REQ DIFF	10.17	6.67	6.67	6.67	6.67	6.67	10.17	
	ESTMEAN	144.65	OBS DIFF	46.60	40.85	31.49	31.01	25.97	18.70	0.41	
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47	2.47	
			D.F	517.79	517.79	517.79	517.79	517.79	517.79	517.79	
			LSD	4.12	4.12	4.12	4.12	4.12	4.12	4.12	

ANALYSIS OF VARIANCE
TIME - 1 WEEK
P < 0.0000446

GROUP				PS	CTRL	40PS	CTRL2	CHEM1	CHEM4	EO1	EO8
PS	FREQ.	(28.0)									
	ESTMEAN	69.06									
40PS	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	72.35	OBS DIFF	3.29							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
CTRL	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	73.82	OBS DIFF	4.76	1.46						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	85.76	OBS DIFF	16.70	13.41	11.94					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	41.10	4.10	4.10					
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	96.05	OBS DIFF	26.99	23.70	22.23	10.29				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.00				
			LSD	4.10	4.10	4.10	4.10				
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	100.87	OBS DIFF	31.81	28.52	27.05	15.11	4.82			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
EO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67		
	ESTMEAN	119.01	OBS DIFF	49.95	46.65	45.19	33.25	22.96	18.14		
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63		
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00		
			LSD	4.10	4.10	4.10	4.10	4.10	4.10		
EO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17	10.17	
	ESTMEAN	120.17	OBS DIFF	51.11	47.82	46.36	34.41	24.12	19.30	1.17	
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47	2.47	
			D.F	517.79	517.79	517.79	517.79	517.79	517.79	517.79	
			LSD	4.12	4.12	4.12	4.12	4.12	4.12	4.12	

ANALYSIS OF VARIANCE
TIME - 2 WEEKS
$P < 0.0000446$

GROUP				PS	CTRL	40PS	CTRL2	CHEM1	CHEM4	BO1	BO8
PS	FREQ.	(28.0)									
	ESTMEAN	65.50									
40PS	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	67.62	OBS DIFF	2.12							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
CTRL	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	67.92	OBS DIFF	2.42	0.30						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	76.23	OBS DIFF	10.73	8.61	8.31					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	41.10	4.10	4.10					
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	78.58	OBS DIFF	13.08	10.96	10.66	2.35				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	84.90	OBS DIFF	19.40	17.27	16.98	8.67	6.32			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
BO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67		
	ESTMEAN	99.00	OBS DIFF	33.50	31.38	31.08	22.77	20.42	14.10		
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63		
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00		
			LSD	4.10	4.10	4.10	4.10	4.10	4.10		
BO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17	10.17	
	ESTMEAN	99.56	OBS DIFF	34.06	31.94	31.64	23.33	20.98	14.66	0.56	
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47	2.47	
			D.F	517.79	517.79	517.79	517.79	517.79	517.79	517.79	
			LSD	4.12	4.12	4.12	4.12	4.12	4.12	4.12	

ANALYSIS OF VARIANCE
TIME - 3 WEEKS
P < 0.0000446

GROUP											
40PS	FREQ.	(28.0)									
	ESTMEAN	54.00									
CTRL	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	55.79	OBS DIFF	1.79							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
PS	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	58.44	OBS DIFF	4.45	2.66						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	62.97	OBS DIFF	8.97	7.19	4.53					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	41.10	4.10	4.10					
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	65.67	OBS DIFF	11.68	9.89	7.23	2.70				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	68.09	OBS DIFF	14.09	12.30	9.65	5.12	2.41			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
EO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67		
	ESTMEAN	86.94	OBS DIFF	32.95	31.16	28.50	23.97	21.27	18.85		
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63		
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00		
			LSD	4.10	4.10	4.10	4.10	4.10	4.10		
EO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17	10.17	
	ESTMEAN	88.63	OBS DIFF	34.63	32.84	30.19	25.66	22.95	20.54	1.69	
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47	2.47	
			D.F	517.79	517.79	517.79	517.79	517.79	517.79	517.79	
			LSD	4.12	4.12	4.12	4.12	4.12	4.12	4.12	
				40PS	CTRL	PS	CHEM1	CTRL2	CHEM4	EO1	EO8

ANALYSIS OF VARIANCE
TIME - 4 WEEKS
P<0.0000446

GROUP				PS	CTRL	40PS	CTRL2	CHEM4	CHEM1	EO8	EO1
PS	FREQ.	(28.0)									
	ESTMEAN	44.75									
CTRL	FREQ.	(28.0)	REQ DIFF	6.67							
	ESTMEAN	47.08	OBS DIFF	2.32							
			S.E.	1.63							
			D.F.	1296.00							
			LSD	4.10							
40PS	FREQ.	(28.0)	REQ DIFF	6.67	6.67						
	ESTMEAN	48.47	OBS DIFF	3.72	1.39						
			S.E.	1.63	1.63						
			D.F.	1296.00	1296.00						
			LSD	4.10	4.10						
CTRL2	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67					
	ESTMEAN	51.91	OBS DIFF	7.15	4.83	3.44					
			S.E.	1.63	1.63	1.63					
			D.F	1296.00	1296.00	1296.00					
			LSD	4.10	4.10	4.10					
CHEM4	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67				
	ESTMEAN	52.79	OBS DIFF	8.04	5.71	4.32	0.89				
			S.E.	1.63	1.63	1.63	1.63				
			D.F	1296.00	1296.00	1296.00	1296.0				
			LSD	4.10	4.10	4.10	4.10				
CHEM1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67			
	ESTMEAN	57.29	OBS DIFF	12.54	10.21	8.82	5.39	4.50			
			S.E.	1.63	1.63	1.63	1.63	1.63			
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00			
			LSD	4.10	4.10	4.10	4.10	4.10			
EO8	FREQ.	(28.0)	REQ DIFF	10.17	10.17	10.17	10.17	10.17	10.17		
	ESTMEAN	71.04	OBS DIFF	26.28	23.96	22.56	19.13	18.24	13.74		
			S.E.	2.47	2.47	2.47	2.47	2.47	2.47		
			D.F	517.79	517.79	517.79	517.79	517.79	517.79		
			LSD	4.12	4.12	4.12	4.12	4.12	4.12		
EO1	FREQ.	(28.0)	REQ DIFF	6.67	6.67	6.67	6.67	6.67	6.67	10.17	
	ESTMEAN	71.83	OBS DIFF	[illegible]	24.75	23.36	19.92	19.04	14.54	0.80	
			S.E.	1.63	1.63	1.63	1.63	1.63	1.63	2.47	
			D.F	1296.00	1296.00	1296.00	1296.00	1296.00	1296.00	517.79	
			LSD	4.10	4.10	4.10	4.10	4.10	4.10	4.12	

SUMMARY TABLE OF F-RATIOS

	SSH	SSE	MSH	MSE	F-RATIO	DFH	DFE	PROB
Group	13358.32	7508.59	1908.33	34.76	54.90	7.0	216.0	144E-43
Time	277875.23	5787.33	55575.05	5.36	10371.11			
Greenhouse-Geiser Adj.	EPSILON	0.82				4.1	885.5	
Group*Time	3788.87	5787.33	108.25	5.36	20.20			
Greenhouse-Geiser Adj.	EPSILON	0.82				28.7	885.5	527E-12

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 1 HOUR
P<0.0000510

GROUP											
CTRL2	FREQ.	(28.0)									
	ESTMEAN	61.85									
CTRL	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	65.13	OBS DIFF	2.48							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
CHEM1	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	64.32	OBS DIFF	3.29	0.81						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	66.75	OBS DIFF	4.91	2.43	1.62					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	11080.00					
			LSD	4.07	4.07	4.07					
EO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49				
	ESTMEAN	68.26	OBS DIFF	6.41	3.94	3.12	1.51				
			S.E.	0.86	0.86	0.86	0.86				
			D.F	605.36	605.36	605.36	605.36				
			LSD	4.08	4.08	4.08	4.08				
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	3.49			
	ESTMEAN	69.12	OBS DIFF	7.27	4.80	3.98	2.37	0.86			
			S.E.	0.62	0.62	0.62	0.62	0.86			
			D.F	1080.00	1080.00	1980.00	1080.00	605.36			
			LSD	4.07	4.07	4.07	4.07	4.08			
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52	2.52		
	ESTMEAN	70.70	OBS DIFF	8.85	6.37	5.56	3.94	2.44	1.58		
			S.E.	0.62	0.62	0.62	0.62	0.62	0.62		
			D.F	1080.00	1080.00	1080.00	1080.00	605.36	1080.00		
			LSD	4.07	4.07	4.07	4.07	4.07	4.07		
EO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	2.52	3.49	3.49	
	ESTMEAN	70.99	OBS DIFF	9.14	6.67	5.85	4.24	2.73	1.87	0.29	
			S.E.	.86	.86	0.86	0.86	.62	0.86	0.86	
			D.F	605.36	605.36	605.36	605.36	1080.00	605.36	605.36	
			LSD	4.08	4.08	4.08	4.08	4.07	4.08	4.08	
				CTRL2	CTRL	CHEM1	PS	EO8	40PS	CHEM4	EO1

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 1 DAY
P< 0.0000510

GROUP				CTRL2	CTRL	PS	CHEM1	EO8	EO1	40PS	CHEM4
CTRL2	FREQ.	(28.0)									
	ESTMEAN	48.62									
CTRL	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	50.12	OBS DIFF	1.50							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	52.04	OBS DIFF	3.41	1.92						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
CHEM1	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	54.84	OBS DIFF	6.22	4.72	2.80					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	1080.00					
			LSD	4.07	4.07	4.07					
EO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49				
	ESTMEAN	56.70	OBS DIFF	8.08	6.58	4.67	1.86				
			S.E.	0.86	0.86	0.86	0.86				
			D.F	605.36	605.36	605.36	605.36				
			LSD	4.08	4.08	4.08	4.08				
EO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	2.52			
	ESTMEAN	56.71	OBS DIFF	8.09	6.59	4.68	1.87	0.01			
			S.E.	0.86	0.86	0.86	0.86	0.62			
			D.F	605.36	605.36	605.36	605.36	1080.00			
			LSD	4.08	4.08	4.08	4.08	4.07			
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52	2.52		
	ESTMEAN	57.01	OBS DIFF	8.39	6.89	4.97	2.17	0.31	0.29		
			S.E.	0.62	0.62	0.62	0.62	0.86	0.86		
			D.F	1080.00	1080.00	1080.00	1080.00	605.36	605.36		
			LSD	4.07	4.07	4.07	4.07	4.08	4.08		
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	3.49	3.49	2.52	
	ESTMEAN	59.51	OBS DIFF	10.89	9.39	7.48	4.67	2.81	2.80	2.50	
			S.E.	0.62	0.62	0.62	0.62	0.86	0.86	0.62	
			D.F	1080.00	1080.00	1080.00	1080.0	605.36	605.36	1080.00	
			LSD	4.07	4.07	4.07	4.07	4.08	4.08	4.07	

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 1 WEEK
# P<0.0000510

GROUP				CTRL	PS	CTRL2	40PS	CHEM1	BO1	BO8	CHEM4
CTRL	FREQ.	(28.0)									
	ESTMEAN	32.55									
PS	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	36.69	OBS DIFF	4.14							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
CTRL2	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	36.85	OBS DIFF	4.29	0.16						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	39.68	OBS DIFF	7.13	2.99	2.84					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	1080.00					
			LSD	4.07	4.07	4.07					
CHEM1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49				
	ESTMEAN	44.31	OBS DIFF	11.76	7.62	7.46	4.62				
			S.E.	0.62	0.62	0.62	0.62				
			D.F	1080.00	1080.00	1080.00	1080.00				
			LSD	4.07	4.07	4.07	4.07				
BO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	2.52			
	ESTMEAN	46.81	OBS DIFF	14.26	10.12	9.96	7.12	2.50			
			S.E.	0.86	0.86	0.86	0.86	0.86			
			D.F	605.36	605.36	605.36	605.36	6605.36			
			LSD	4.08	4.08	4.08	4.08	4.08			
BO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	2.52		
	ESTMEAN	47.11	OBS DIFF	14.56	10.42	10.26	7.43	2.80	0.30		
			S.E.	0.86	0.86	0.86	0.86	0.86	0.62		
			D.F	605.36	605.36	605.36	605.36	605.36	1080.00		
			LSD	4.08	4.08	4.08	4.08	4.08	4.07		
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52	3.49	3.49	
	ESTMEAN	47.59	OBS DIFF	15.04	10.90	10.74	7.91	3.28	0.78	0.48	
			S.E.	0.62	0.62	0.62	0.62	0.62	0.86	0.86	
			D.F	1080.00	1080.00	1080.00	1080.0	1080.00	605.36	605.36	
			LSD	4.07	4.07	4.07	4.07	4.07	4.08	4.08	

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 2 WEEKS
P<0.0000510

GROUP				CTRL	CTRL2	PS	CHEM4	40PS	EO1	EO8	CHEM1
CTRL	FREQ.	(28.0)									
	ESTMEAN	29.96									
CTRL2	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	32.70	OBS DIFF	2.74							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	34.80	OBS DIFF	4.83	2.09						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	37.03	OBS DIFF	7.06	4.32	2.23					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	1080.00					
			LSD	4.07	4.07	4.07					
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52				
	ESTMEAN	37.09	OBS DIFF	7.13	4.39	2.30	0.07				
			S.E.	0.62	0.62	0.62	0.62				
			D.F	1080.00	1080.00	1080.00	1080.00				
			LSD	4.07	4.07	4.07	4.07				
EO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49			
	ESTMEAN	38.91	OBS DIFF	8.95	6.21	4.12	1.89	1.82			
			S.E.	0.86	0.86	0.86	0.86	0.86			
			D.F	605.36	605.36	605.36	605.36	6605.36			
			LSD	4.08	4.08	4.08	4.08	4.08			
EO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	2.52		
	ESTMEAN	39.03	OBS DIFF	9.07	6.33	4.24	2.01	1.94	0.12		
			S.E.	0.86	0.86	0.86	0.86	0.86	0.62		
			D.F	605.36	605.36	605.36	605.36	605.36	1080.00		
			LSD	4.08	4.08	4.08	4.08	4.08	4.07		
CHEM1	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52	3.49	3.49	
	ESTMEAN	39.16	OBS DIFF	9.20	6.46	4.36	2.13	2.06	0.24	0.13	
			S.E.	0.62	0.62	0.62	0.62	0.62	0.86	0.86	
			D.F	1080.00	1080.00	1080.00	1080.0	1080.00	605.36	605.36	
			LSD	4.07	4.07	4.07	4.07	4.07	4.08	4.08	

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 3 WEEKS
P<0.0000510

GROUP											
CTRL	FREQ.	(28.0)									
	ESTMEAN	24.62									
CTRL2	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	28.22	OBS DIFF	3.60							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
CHEM1	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	29.07	OBS DIFF	4.45	0.85						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	29.58	OBS DIFF	4.96	1.36	0.51					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	1080.00					
			LSD	4.07	4.07	4.07					
PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52				
	ESTMEAN	31.02	OBS DIFF	6.40	2.80	1.95	1.44				
			S.E.	0.62	0.62	0.62	0.62				
			D.F	1080.00	1080.00	1080.00	1080.00				
			LSD	4.07	4.07	4.07	4.07				
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52			
	ESTMEAN	32.12	OBS DIFF	7.50	3.89	3.05	2.53	1.09			
			S.E.	0.62	0.62	0.62	0.62	0.62			
			D.F	1080.00	1080.00	1080.00	1080.00	1080.00			
			LSD	4.07	4.07	4.07	4.07	4.07			
EO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	3.49		
	ESTMEAN	34.15	OBS DIFF	9.53	5.92	5.08	4.56	3.13	2.03		
			S.E.	0.86	0.86	0.86	0.86	0.86	0.86		
			D.F	605.36	605.36	605.36	605.36	605.36	605.36		
			LSD	4.08	4.08	4.08	4.08	4.08	4.08		
EO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	3.49	2.52	
	ESTMEAN	34.76	OBS DIFF	10.14	6.54	5.69	5.18	3.74	2.65	0.61	
			S.E.	0.86	0.86	0.86	0.86	0.86	0.86	0.62	
			D.F	605.36	605.36	605.36	605.36	605.36	605.36	1080.00	
			LSD	4.08	4.08	4.08	4.08	4.08	4.08	4.07	
				CTRL	CTRL2	CHEM1	40PS	PS	CHEM4	EO1	EO8

ANALYSIS OF VARIANCE
% INITIAL FORCE
TIME - 4 WEEKS
P<0.0000510

GROUP				CTRL	CTRL2	PS	CHEM4	CHEM1	40PS	EO8	EO1
CTRL	FREQ.	(28.0)									
	ESTMEAN	20.74									
CTRL2	FREQ.	(28.0)	REQ DIFF	2.52							
	ESTMEAN	22.28	OBS DIFF	1.53							
			S.E.	0.62							
			D.F.	1080.00							
			LSD	4.07							
PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52						
	ESTMEAN	23.75	OBS DIFF	3.00	1.47						
			S.E.	0.62	0.62						
			D.F.	1080.00	1080.00						
			LSD	4.07	4.07						
CHEM4	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52					
	ESTMEAN	24.85	OBS DIFF	4.10	2.57	1.10					
			S.E.	0.62	0.62	0.62					
			D.F	1080.00	1080.00	1080.00					
			LSD	4.07	4.07	4.07					
CHEM1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49				
	ESTMEAN	26.46	OBS DIFF	5.72	4.18	2.71	1.61				
			S.E.	0.62	0.62	0.62	0.62				
			D.F	1080.00	1080.00	1080.00	1080.00				
			LSD	4.07	4.07	4.07	4.07				
40PS	FREQ.	(28.0)	REQ DIFF	2.52	2.52	2.52	2.52	2.52			
	ESTMEAN	26.57	OBS DIFF	5.83	4.30	2.82	1.72	0.11			
			S.E.	0.62	0.62	0.62	0.62	0.62			
			D.F	1080.00	1080.00	1080.00	1080.00	1080.00			
			LSD	4.07	4.07	4.07	4.07	4.07			
EO8	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	3.49		
	ESTMEAN	27.85	OBS DIFF	7.10	5.57	4.10	3.00	1.38	1.27		
			S.E.	0.86	0.86	0.86	0.86	0.86	0.86		
			D.F	605.36	605.36	605.36	605.36	605.36	605.36		
			LSD	4.08	4.08	4.08	4.08	4.08	4.08		
EO1	FREQ.	(28.0)	REQ DIFF	3.49	3.49	3.49	3.49	3.49	3.49	2.52	
	ESTMEAN	28.22	OBS DIFF	7.48	5.94	4.47	3.37	1.76	1.65	0.37	
			S.E.	0.86	0.86	0.86	0.86	0.86	0.86	0.62	
			D.F	605.36	605.36	605.36	605.36	605.36	605.36	1080.00	
			LSD	4.08	4.08	4.08	4.08	4.08	4.08	4.07	

APPENDIX 6

Test of significance for FORCE using unique sums of squares.
3 loop chain

	SS	DF	MS	F	Sig. of F
within cells	6319.11	45	140.2		
	500964.97	4	125241.24	891.88	.000
linear	489468.14	1	489468.14	3485.63	.000
quadrate	9864.96	1	9864.96	70.25	.000
cubic	1379.38	1	1379.38	9.82	.000
quartic	252.48	1	252.48	1.80	.000

489468.14/500964.97 = 0.977

Test of significance for FORCE using unique sums of squares.
4 loop chain

	SS	DF	MS	F	Sig. of F
within cells	9438.82	81	116.53		
	881367.37	8	110170.92	945.44	.000
linear	870432.68	1	870432.68	7469.69	.000
quadrate	6003.81	1	6003.81	51.52	.000
cubic	2487.52	1	2487.52	21.35	.000
quartic	335.56	1	335.56	2.88	.094
5th	342.58	1	342.58	2.94	.090
6th	1407.04	1	1407.04	12.07	.001
7th	244.11	1	244.44	2.10	.151
8th	133.75	1	133.75	0.98	.326

870432.68/881367.37 = 0.987